Spring 1961

Epidermal Patterns of the Leaf Blade in Selected Andropogoneae

Yong No Lee
Fort Hays Kansas State College

EPIDERMAL PATTERNS OF THE LEAF BLADE IN SELECTED ANDROPOGONEAE

being

A thesis presented to the Graduate Faculty of
Fort Hays Kansas State College in
partial fulfillment of the requirements for
the Degree of Master of Science

by

Yong No Lee, B. S.
Seoul National University, Seoul, Korea

Date May 24, 1961 Approved Howard C. Reynolds
Major Professor

Richard G. Cooke
Chairman Graduate Council

ABSTRACT OF THESIS

Epidermal patterns of the widest portion of the leaf blade of selected members of the Andropogoneae were studied. These included 23 genera and 71 species, some of which were duplicates, making a total of 83 entries. The specimens were collected by Dr. H. C. Reynolds in the Andropogoneae Nursery, a common transplant garden having similar environmental conditions and located at Oklahoma State University at Stillwater, Oklahoma.

Spidermal patterns were studied mainly by the peel method, using acetone and cellulose acetate film. These were compared with peridermal sections and some whole cleared mounts which were made by Dr. Reynolds.

The leaf epidermal elements, silica cells, bicellular-microhairs, cushion hairs, macro-hairs, swollen hairs, bulbous hairs, papillae, stomata, and long cells were observed on the abaxial and adaxial surfaces from the leaf margin to mid vein. Also, the arrangement of epidermal elements, silica cells, stomata, and trichomes was examined. These were observed on the abaxial surface (lower surface) more in detail than on the adaxial surface (upper surface).

Bicellular-microhairs and silica cells were found to be the most diagnostic characters, and the arrangement of silica cells, trichomes and stomata were also found to be important for classification of species of the Andropogoneae.

In the members of the Andropogoneae investigated, it was found that the cushion hairs, swollen hairs, spicules, papillae and stomatal distribution were more variable characters. Epidermal patterns are

more important for identification of grasses by vegetative characters than the individual elements.

ACKNOWLEDGEMENT

I would like to thank Dr. Howard C. Reynolds for the loan of his materials, and whose knowledge of the Andropogoneae and assistance in research greatly helped in the preparation of this thesis. I would also like to thank Dr. G. W. Tomanek, Chairman of the Division of Biological Sciences who made available research facilities. Thanks are due Professor Henry McFarland for aid in photomicrographic equipment.

TABLE OF CONTENTS

INTRODUCTION

During the past half century that part of botany, and in fact all biological sciences which deal with evolution and classification, have entered a new era by the use of new tools for solving evolutionary and taxonomic problems.

The anatomical and histological features of the grass leaf have been studied from the systematic point of view since the end of the last century.

An important paper on leaf structure is that by Prat (1936) who examined the features of the leaf epidermis. He showed that epidermal features are correlated with characteristics of cross sections of leaves and can be divided into two major types, Festucoid and Panicoid. In addition, Prat found that the Panicoid type can be classified into two subtypes, Eupanicoid and Chloridoid. The Chloridoid subtype is characterized by globose or club-shaped bicellular micro-hairs and saddle-shaped silica cells, while the Eupanicoid subtype has rodlike micro-hairs and dumbbell-shaped silica cells. Prat found that the subtypes are in agreement with morphological features and proposed the systematic grouping of Supanicoids and Chloidoids under the sub-family Panicoideae.

While the anatomy and histology of grass leaves has been studied more recently by various investigators, most of the papers have dealt with genera which were not at all, or only scantily, examined by Prat and other earlier investigators.

Prat (1948) stated that "The subfamilies Bambusoideae and Panicoideae possess the most complicated shapes of silica cells such as in the Eupanicoid tribes, and in the Chloridoid tribes. In the subfamily Festucoideae only the simplest types of silica cells are present. In Bambusoideae and Panicoideae, there are bicellular hairs, thread-like in the Eupanicoid tribes, and swollen in the Chloridoid. The cushion hairs, too, are correlated with the Panicoideae subfamily. The true Festucoideae never possess either bicellular or cushion hairs."

Prat (1948) said that characters are based on the distribution of epidermal cells. The distribution of the different types of cells on all the organs of the plant (leaves, internodes, glumes, etc.) obey precise rules and show notable differences from one species to another, and within a species from one variety to another. The distributive characters thus constitute a second category of taxonomic importance. They are less fundamental but allow more delicate distinctions than the structural ones, as they provide a means of distinguishing smaller groups (species or varieties) instead of subfamilies and tribes. For this reason they are the most valuable for taxonomic or genetic work.

Metcalfe (1954) recently pointed out that certain characters of the epidermis, such as the shape of subsidiary cells of the stomatal apparatus, are systematically important as well as the silica cells and the microhairs. Metcalfe (1960) in his book, Anatomy of the Monocotyledons, Part II Gramineae, states: "Although all descriptions of the epidermis in this book have been drawn up with this viewpoint

in mind, the reader should remember that authors of other books and articles have not necessarily done likewise."

As mentioned above by various investigators, structural characters of the epidermis of Gramineae are one of the significant characters for grass classification.

Tateoka (1958) reported that two species of Arundinella, A. Nepalensis Trin., and A. decempedalis Tanowsky, showed saddleshaped silica cells while in eleven other species of the same genus they are dumbbell-shaped.

H. C. Reynolds (1959) studied morphology of the leaf blade of selected members of the Andropogoneae, principally leaf vascularization patterns and amounts of lignification, and found significant differences between species. While this work does not investigate epidermal patterns, it does note the epidermal appendages as seen in cross section as described in his key to the species.

This epidermal pattern was studied with selected Andropogoneae from taxonomic view point in the present study.

A general background in grass morphology was obtained from Arber (1934), and the books of Esau (1957, 1960) were helpful for the general knowledge of anatomy. The peel method was described by Lonert (1960).

MATERIALS AND METHODS

Material

The widest portion of the leaf blade of selected members of the Andropogoneae as studied. These included 23 genera and 71 species, some of which were duplicates, making a total of 83 entries which were collected by Dr. H. C. Reynolds in the Andropogoneae Garden at Oklahoma State University, Stillwater, Oklahoma.

Methods

The epidermis was peeled from a leaf blade with cellulose acetate film (0.15 mm. in thickness). The dried leaves were immersed in a glycerin, alcohol, and water solution for two days. These were washed for 24 hours in fresh water and excess water was removed from the leaf surface by blotting. Acetone was placed on the leaf surface, then covered by the cellulose acetate which was pressed down tightly with a finger for about three minutes, the cellulose acetate stripped off and the cellulose acetate piece was fixed on a glass slide.

Observation was made under the microscope with 100 X and 400 X-magnification. Photomicrographs were made of both epidermal surfaces to use as illustrations, and these were supplemented by line drawings of silica cells, cork cells, and trichomes.

For purposes of comparison, peridermal sections, cross section of leaf blades, and some whole cleared mounts were observed which were made by Dr. Reynolds.

OBSERVATIONS

The leaf epidermal elements, silica cells, bicellular-microhairs, cushion hairs, macrohairs, swollen hairs, bulbous hairs, papillae, stomata, and long cells were observed on the abaxial (lower surface) and adaxial surfaces (upper surface) from leaf margin to mid vein. Also, the arrangement of the preceding epidermal elements was examined. These were observed on the abaxial surface more in detail than on the adaxial surface, because the abaxial surface epidermal patterns were more varied than those of the adaxial surface.

All of these observations are described on the following pages.

Fig. No.

1. Andropogon barbinodis Lag.

   The abaxial surface has stomata and swollen hairs alternating in the same row, and three or four rows of these to one row of silica cells.

   The adaxial surface has many silica cells in two or three rows on the vein portion. The silica cells are dumbbell-shaped, and often compacted.

   Bicellular hairs are on both leaf surfaces, and are few. Swollen hairs alternate with stomata and bicellular hairs in the same row.

   Long cells are slightly undulated on both sides.

   Both epidermal surfaces are nearly plane.

2. Andropogon bicormis

The abaxial surface has silica cells and swollen hairs alternating in the same row, which alternate with one row of stomata, or occasionally two.

The adaxial surface has two rows of lanceolate hairs on each major vein to two or three rows of single row swollen hairs above the minor veins. The adaxial surface is lacking in stomata. The silica cells are dumbbell-shaped.

Long cells of the lower surface are not as deeply undulate as those of the adaxial surface. The cells of the upper surface are deeply wavy on the marginal portion of the leaf.

3. Andropogon distachyus L.

The abaxial surface has one row of silica cells alternating with one or two rows of stomata. Swollen hairs alternate with the stomata in the same row.

The silica cells are dumbbell-shaped, sometimes appearing H-shaped. The adaxial surface has acuminate bicellular hairs and the lower surface has long cushion hairs, in addition to papillae. Long cells are shallowly wavy.

The adaxial surface of the epidermis is slightly undulate to nearly plane.

4. Andropogon gabonensis

The abaxial surface has several small silica cells alternating

with large ovate hairs in the same row, and this alternating with two rows of stomata alternating with papillate hairs in the same row.

Stomata occur on the abaxial surface only.

The papillae are the rather uniform size and very abundant, occurring in rows down the middle of the long cells.

The silica cells are not well developed.

The adaxial surface has larger round hairs than the abaxial surface.

Papillae are few compared to the lawer surface.

Bicellular hairs occur on the abaxial surface.

Long cells are deeply wavy on both surfaces and form loop-like protrusions.

5. Andropogon gayanus Kunth

The abaxial surface has a group of silica cells alternating with single ovate hairs in the same row. The silica cells are nearly dumbbell-shaped and some are nodulose. Cushion hairs, ovate hairs, and papillae are on both surfaces of the leaf. Bicellular hairs occur on the abaxial surface. Long cells are shallowly waved. The papillae occur in conspicuous rows on both epidermal surfaces.

6. Andropogon gerardi Vitman

The abaxial surface has groups of silica cells alternating with single ovate hairs in the same row, and this alternating with two rows of stomata. The silica cells are dumbbell-shaped. The abaxial surface has bicellular hairs.

Both surfaces of the leaf have small ovate hairs, and the marginal portion of the leaf has many spicules.

7. Andropogon hallii Hack.

The abaxial surface has silica cells and spindle shaped hairs alternating the same row, and this to one row of stomata,
The silica cells are sometimes well developed and dumbbell-shaped.
Both surfaces have spindle shaped or clavate hairs and the lower Surface has a few bicellular hairs. Stomata are on the lower surface only. The adaxial surface is deeply undulate. Long cells are deeply wavy with the loops touching each other.
Andropogon hallii may be distinguished from Andropogon gerardi, in that the former has conspicuous spindle-shaped hairs on both epidermal surfaces which are lacking in Andropogon gerardi.

8. Andropogon lateralis

The abaxial surface has silica cells and bulbous or ovate hairs alternating in the same row, and this row to one or two rows of stomata.
Bicellular hairs occur on the lower surface. The adaxial surface has many long cushion hairs and bulbous swollen hairs.
Stomata occur on the abaxial surface.
Long cells are shallowly undulate on both sides.
A distinctive feature of the abaxial surface is the numerous acuminate bulbous-based hairs. On the adaxial surface the swollen hairs are very closely spaced in straight rows, either single or double.

9. Andropogon pseudapricus Stapf

The abaxial surface has silica cells and bulbous hairs alternating in the same row, and this row to a row consisting of stomata and swollen hairs alternating. The silica cells are well developed and dumbbell-shaped.

Both surfaces of the leaf have veins with cushion hairs over them. Swollen and bulbous hairs are numerous on both surfaces. Bicellular hairs occur on the abaxial surface only.

Long cells are deeply wavy on both surfaces.

10. Andropogon saccharoides Swartz

The abaxial surface has stomata and clavate or swollen hairs in the same row and two or four rows of these to one to three rows of silica cells. Silica cells are numerous. The silica cells are well developed and nearly uniformly dumbbell-shaped.

Both surfaces have bicellular hairs and clavate hairs.

Stomata are on the abaxial surface only.

Long cells are shallowly wavy on both surfaces.

11. Andropogon spathiflorus

The abaxial surface has bulbous hairs and silica cells alternating in the same row, and one row of these elements to one row of stomata. The stomata alternate with papillae, in the same row.

The adaxial surface has many silica cells on the vein portion.

The silica cells are dumbbell-shaped.

Bicellular hairs, many bulbous hairs and spicules occur on the

abaxial surface and a few bicellular hairs and swollen hairs on the adaxial surface.

Long cells are deeply wavy on both surfaces.

Both surfaces of the leaf are strongly undulate.

12. Andropogon ternarius Michx.

The abaxial surface has silica cells and bulbous hairs alternating in the same row, and each row of these elements to one row of stomata. Conspicuously convex epidermal cells alternate with the stomata in the same row and are sometimes papillate.

The adaxial surface has a few silica cells in between the swollen hairs.

Silica cells are dumbbell-shaped.

Both surfaces have bicellular hairs, and bulbous hairs are on the upper surface only.

13. Apluda varia

The abaxial surface has nodulose silica cells and bulbous or swollen hairs alternating in the same row, and one to three rows of these elements to one row of stomata. The nodulose silica cells are quite distinctive, but the dumbbell-shaped silica cells are also present.

The adaxial surface has ovate hairs and the lower surface has many bulbous hairs.

Both surfaces have cushion hairs.

Long cells are shallowly wavy on both surfaces.

14. Bothriochola decipiens C. E. Hubb.

The abaxial surface has several silica cells and bulbous hairs alternating in the same row, and one or two rows of these elements to one row of stomata with papillae.

Both surfaces have bulbous hairs and the adaxial surface has bicellular hairs.

Stomata occur on both surfaces.

Long cells are wavy on the marginal portion of the blade on both surfaces.

15. Bothriochola glabra A. Camus

The abaxial surface has silica cells and cork cells alternating in the same row, and one to three rows of these elements to two to four rows of stomata.

The adaxial surface has several silica cells and swollen hairs alternating in the same row.

The silica cells are dumbbell-shaped, cruciate-shaped and double-blade-axe-shaped.

Bicellular hairs are few and on the lower surface.

Long cells are deeply wavy on both surfaces.

16. Bothriochola insculpta

The abaxial surface has stomata and ovate papillae alternating in the same row, and one or two rows of these elements to one or three rows of silica cells. The silica cells on the abaxial surface occur in two or three rows above the major veins and

usually in a single row above the minor veins. The silica cells are dumbbell-shaped and cruciate-shaped.

The abaxial surface has many papillate hairs.

Bicellular hairs occur on both surfaces.

Long cells are shallowly undulate on both surfaces.

Stomata occur on both surfaces, but are few in the adaxial surface.

17. Bothriochloa insculpta A. Camus

The abaxial surface has stomata and ovate papillae alternating in the same row, and two to four rows of these elements to one of silica cells except on the vein portion.

The silica cells are nearly dumbbell-shaped and some silica cells are nodulose. Both surfaces have bicellular hairs and the abaxial surface has cushion hairs.

The marginal portion of both leaf surfaces have spicules and deeply wavy long cells.

The ovate papillae form a very conspicuous pattern on the abaxial epidermis as they are regularly spaced in definite rows.

The stomata are shortened fusiform instead of elongated as in Bothriochloa "insculpta?"

18. Bothriochloa intermedia A. Camus

The abaxial surface has stomata and swollen hairs, alternating in the same row, and three or four rows of these elements to two or three rows of silica cells. The adaxial surface has several silica cells and ovate hairs alternating in the same row. Silica cells are

dumbbell-shaped. Both surfaces have long cushion hairs, swollen ovate bulbous hairs and bicellular hairs.

Long cells are deeply wavy on the vein portion on both surfaces.

The abaxial surface has many papillate hairs.

19. Bothriochola intermedia A. Camus

The abaxial surface has one to three rows of silica cells alternating with three or four rows of stomata.

The silica cells are dumbbell-shaped.

Both surfaces have bicellular hairs and very small bulbous hairs.

Long cells are deeply wavy on both surfaces.

20. Bothriochloa intermedia A. Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and one or two rows of these elements to one to two rows of silica cells.

The silica cells are nearly dumbbell-shaped and these developed well on the vein portion. Both surfaces have bicellular hairs and the abaxial surface has more papillate hairs.

Long cells are deeply wavy on the marginal portion on both surfaces.

21. Bothriochola intermedia A Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and one or two rows of these elements to one or two rows of silica cells except on the vein portion.

The silica cells are nearly dumbbell-shaped and some are modulose.

The abaxial surface has many papillae, and more swollen hairs than the

adaxial surface.

Bicellular hairs occur on both surfaces but few on the lower surface.

Long cells are deeply wavy on both surfaces.

The swollen hairs or papillae are very numerous in regular closely-shaped rows.

22. Bothriochloa intermedia A Camus

The abaxial surface has stomata and clavate hairs alternating in the same row and one to three rows of these elements to one or two rows of silica cells.

The vein portion of the lower surface has three rows of broad dumbbell-shaped silica cells.

Both surfaces have clavate hairs and bicelluair hairs, and the lower surface has many papillate hairs.

Long cells are deeply wavy on both surfaces.

23. Bothriochloa ischaemum Keng (Amoy, China)

The abaxial surface has stomata and papillae alternating in the same row, and two to four of these elements to one row of silica cells, except on the vein portion where there are three rows of silica cells.

Silica cells are dumbbell-shaped.

Both surfaces have bicellular hairs and the adaxial surface has cushion hairs.

Long cells are deeply wavy on the marginal portion of both surfaces of the leaf.

The stomata are elliptic to nearly round.

24. Bothriochloa ischaemum Keng (Formosa)

The abaxial surfaces have stomata and papillae alternating in the same row and two or three rows or more of these elements to one row of silica cells except on the vein portion.

The lower surface has more papillae than the upper surface.

The adaxial surface has several silica cells and long bulbous hairs alternating in the same row.

Both surfaces have cushion hairs and bicellular hairs.

The marginal portion of the leaf has spicules.

Long cells are deeply wavy on both surfaces, and the upper surface is undulate.

25. Bothriochloa ischaemum Keng (Austria)

The abaxial surface has stomata and swollen hairs or bulbous hairs alternating in the same row and two to four rows of these elements to one row of dumbbell-shaped silica cells.

Both surfaces have cushion hairs, swollen hairs, and bulbous hairs.

Long cells are deeply wavy on the upper surface.

26. Bothriochloa erianthoides C. E. Hubbard

The abaxial surface has stomata and swollen hairs alternating in the same row and four to six rows of these elements to one to three rows of silica cells. The adaxial surface has many silica cells, with two or three rows on the vein portion.

The silica cells are dumbbell-shaped.

Bicellular hairs are on both surfaces of the leaf.

Long cells are shallowly wavy on both sides.

Stomata occur on both surfaces and are elliptic to rounded in shape.

27. Bothriochloa pertusa A. Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and one or two rows of these elements to one or two rows of silica cells. Silica cells are nearly dumbbell-shaped and some are nodulose.

Cushion hairs and bicellular hairs are on both surfaces.

Swollen hairs and globose hairs are abundant on the lower surface and spicules occur on the upper surface.

The abaxial surface has many papillate hairs.

Long cells are deeply wavy on the marginal portion of both sides of the leaf.

28. Bothriochloa radicans A. Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and each row of these elements to a single row

of silica cells containing several silica cells alternating with swollen hairs. Silica cells are either somewhat dumb-bell-shaped, or nodulose.

Bicellular hairs occur on both surfaces. Swollen hairs, spindle shaped hairs and papillate hairs are many on the abaxial surface. Long cells are deeply wavy on the marginal portion of the leaf on both sides.

29. Bothriochloa radicans A Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and two to four rows of these elements to one or two rows of silica cells. Silica cells are dumbbell-shaped. Cushion hairs, papillate hairs, and many swollen hairs occur on both surfaces.

Long cells are shallowly wavy on the marginal portion of the leaf on both sides.

The adaxial surface is undulate.

30. Bothriochloa saccharoides Rydb.

The abaxial surface has stomata and swollen hairs alternating in the same row and two rows of these elements to one or two rows of silica cells. Silica cells are dumbbell-shaped and nodulose.

Bicellular hairs, papillate hairs, and swollen hairs are more on the abaxial surface than the adaxial surface. Long cells are deeply wavy on the marginal portion of the leaf on both sides.

31. Bothriochloa venusta A Camus

The abaxial surface has stomata and swollen hairs alternating in the same row and two to three rows of these elements to one or two rows of silica cells.

The silica cells are dumbbell-shaped.

Cushion hairs and bicellular hairs are numerous on the abaxial surface and the upper surface has papillate hairs, and bulbous hairs.

Stomata are on both surfaces of the leaf.

The long cells on the marginal portion of the blade are more deeply waved than toward the middle of the blade on both surfaces.

32. Capillipedium parviflorum Stapf

The abaxial surface has stomata and swollen hairs alternating in the same row and each row of these elements to one or two rows of silica cells with cushion hairs or long bicellular hairs.

The silica cells are dumbbell-shaped.

Both surfaces have many cushion hairs, bicellular hairs, and swollen hairs.

The abaxial surface has more papillate hairs than the adaxial.

The long cells are shallowly wavy on the marginal portion of both sides.

33. Capillipedium spicigera

The abaxial surface has stomata and swollen hairs alternating in the same row and one to two rows of these elements to one or

two rows of several silica cells and swollen hairs or large bicellular cells alternating in the same row.

The silica cells are dumbbell-shaped.

Bicellular hairs, papillate hairs and swollen hairs are more numerous on the abaxial surface than on the adaxial surface.

Long cells are deeply wavy on both sides.

Long bulbous-based spicules are present, and only slightly curved.

Large rectangular cells are scattered in the abaxial epidermis.

Leaf margins have blunt bicellular papillae.

34. Chrysopogon aucheri Stapf

The abaxial surface has two or three rows of silica cells alternating with one row of stomata. Some silica cells and bulbous hairs or bicellular hairs alternate in the same row. The silica cells are double-bladed-axe-shaped, or cruciate.

Long cells are deeply waved on both surfaces.

35. Chrysopogon montanus Trin.

The abaxial surface has two or three rows of silica cells alternating with one row of stomata. Some silica cells and bulbous hairs alternate in the same row. Each silica cell is usually accompanied by a single cork cell. The epidermal pattern is almost the same as Chrysopogon aucheri, but all the cells of Chrysopogon montanus are smaller.

The long cells are deeply wavy on both surfaces.

36. Cleistachne sorghoides Benth.

The abaxial surface has stomata and swollen hairs alternating in the same row, and two to four rows of these to one or two rows of silica cells. The silica cells are dumbbell-shaped and some are nodulose.

The adaxial surface has distinct rows of silica cells.

Cushion hairs and bicellular hairs are on both surfaces of the leaf.

37. Cymbopogon bombycinus Domin.

The abaxial surface has one row of silica cells alternating with four rows of stomata. The silica cells are dumbbell-shaped but these are not well developed.

Hairs are lacking on both surfaces which are nearly plane.

Long cells are shallowly wavy on both sides.

Epidermal cells on the adaxial surface are very large with a slightly convex outer wall.

38. Cymbopogon excavatus

The abaxial surface has several silica cells alternating with each lanceolate hair in the same row. In some areas there are two rows of stomata to one row of silica cells, but in other areas the arrangement is variable. Some rows of silica cells alternate with only cork cells in the same row on both surfaces.

The silica cells are dumbbell-shaped or cruciate.

Both sides have bicellular hairs. The marginal portion of the leaf has spicules. The long cells are deeply wavy on both sides.

39. Cymbopogon hookeri

The abaxial surface has silica cells and swollen hairs or lanceolate hairs alternating in the same row, and one or two rows of these elements to one row of stomata. The silica cells are nearly dumbbell-shaped or sometimes cruciate. Bicellular hairs occur on the lower surface.

Long cells are shallowly wavy on both sides and the upper surface is undulate.

The large lanceolate hairs are a conspicuous feature of the abaxial epidermis.

40. Cymbopogon martinii

The abaxial surface has one row of silica cells alternating with two to four rows of stomata.

The silica cells are dumbbell-shaped.

The adaxial surface has small bicellular hairs. Stomata occur on both surfaces.

Long cells are deeply wavy on the marginal portion of the leaf on both sides.

41. Cymbopogon sp

The abaxial surface has two or three rows of silica cells which are very distinct on the vein portion.

The silica cells are dumbbell-shaped or sometimes cruciate. Stomata and very small bicellular hairs occur on both surfaces. Long cells are shallowly wavy on both sides.

Both surfaces are generally lacking in swollen hairs, papillae and cushion hairs, or other vestiture. Distinctive elliptic to rectangular-shaped short cells are present between the long cells.

Silica cells occur in two to three adjacent rows alternating with up to seven rows of stomata. The stomatal rows are sometimes indistinct.

42. Diectomis Sp. Kunth

The abaxial surface of the leaf has stomata and swollen hairs alternating in the same row and one row of these elements to one row of silica cells with bulbous hairs. The Silica cells are nearly dumbbell-shaped. The abaxial surface has swollen hairs and both surfaces have large pointed bicellular hairs and pointed bulbous hairs.

Long cells are shallowly wavy on both sides.

43. Dichanthium annulatum Stapf

The abaxial surface has stomata and swollen hairs alternating in the same row, and one row of these elements tc one or two rows of filica cells. The silica cells are dumbbell-shaped and some are nodulose. Many bicellular hairs occur on the abaxial surface but

only a few on the adaxial surface. Long cells are shallowly wavy in both surfaces. The abaxial surface is strongly papillose.

44. Dichanthium aristatum C. E. Hubbard

The abaxial surface of the leaf has several silica cells and bulbous hairs alternating in the same row and one or two rows of these elements to one or two rows of stomata. The silica cells are dumbbell-shaped. The adaxial surface has many bulbous or lanceolate hairs and the abaxial surface has a few bicellular hairs.

Long cells are deeply wavy on the adaxial surface.

45. Dichanthium caricosum

The abaxial surface has several silica cells and spindle shaped hairs alternating in the same row and one row of these to one row of stomata with swollen hairs or clavate hairs occurring in the same row. The silica cells are nearly dumbbell-shaped and some are nodulose. The abaxial surface has clavate, bulbous, and spindle shaped hairs. The adaxial surface has contiguous bulbous hairs and bicellular hairs.

Long cells are deeply wavy on the marginal portion of both surfaces.

46. Dichanthium caricosum A. Camus (Malay)

The abaxial surface of the leaf has several silica cells and bulbous hairs alternating in the same row and one row of these elements to one row of stomata with clavate or swollen hairs.

The silica cells are dumbbell-shaped. The adaxial surface has bicellular hairs and contiguous swollen hairs. Long cells are deeply wavy on the marginal portion of both surfaces. The pattern is similar to number 45 but its hairs are smaller.

47. Dichanthium caricosum var. media

The abaxial surface of the leaf has several silica cells to each bulbous hair alternating in the same row, and one or two rows of these elements to one row of stomata with clavate hairs. Silica cells are dumbbell-shaped, cruciate, and nodulose.

The adaxial surface has bicellular hairs.

Long cells are deeply wavy on the marginal portion of the leaf on both surfaces.

48. Dichanthium papillosum Stapf

The abaxial surface of the leaf has several silica cells to swollen hairs alternating in the same row, and one row of these to one row of stomata with bulbous hairs. The silica cells are nearly dumbbell-shaped. Both surfaces have bicellular hairs and the adaxial surface has cushion hairs.

The lower surface has many papillae.

Long cells are deeply wavy on both sides.

49. Dichanthium sericeum A. Camus

The abaxial surface of the leaf has stomata and swollen hairs alternating in the same row, and one row of these elements to one row of silica cells with bulbous hairs or cushion hairs. The

silica cells are dumbbell-shaped. The abaxial surface has many long cushion hairs and the adaxial surface has short cushion hairs.

Long cells are deeply wavy on the marginal portion.

Bicellular hairs occur on the abaxial surface.

50. Erianthus longisetosus

The abaxial surface of the leaf has stomata and swollen hairs alternating in the same row and one row of these elements to one or two rows of silica cells with swollen hairs. The silica cells are dumbbell-shaped and many of these are on the marginal portion.

Bicellular hairs are on both surfaces.

Long cells are deeply wavy on both surfaces.

51. Erianthus ravennae (L.) Beauv.

The abaxial surface has stomata and clavate hairs alternating in the same row, and two or three rows of these to one or two rows of silica cells with spindle shaped hairs. The silica cells are few, dumbbell-shaped and nodulose.

Long cells are shallowly wavy on both sides.

The adaxial surface is very undulate.

52. Erianthus sp.

The abaxial surface of the leaf has silica cells and large ovate hairs alternating in the same row and one row of these elements to two or more rows of stomata. The silica cells are double-bladed-axe-shaped and nodulose. Bicellular hairs occur

on both surfaces.

Long cells are deeply wavy on both surfaces.

53. Eremopogon faveolatus Stapf

The abaxial surface has silica cells and swollen hairs alternating in the same row and one row of these elements to several rows of swollen hairs. The silica cells are dumbbell-shaped.

The abaxial surface has many tufted swollen hairs and the adaxial surface a few bulbous hairs.

Long cells are deeply wavy.

Large finger-like papillae which appear bicellular are very conspicuous.

Several rows of stomata to each one or two rows of silica cells occur on both surfaces.

54. Euclasta condylotricha Stapf

The abaxial surface of the leaf has stomata and clavata hairs alternating in the same row and two to five rows of these elements to one or two rows of silica cells. The elements make a regular pattern. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs.

Long cells are deeply wavy on both surfaces.

Rows of swollen hairs are very uniform.

55. Heteropogon contortus Roem. & Schultz

The abaxial surface of the leaf has stomata and clavate hairs alternating in the same row and two to five rows of these to

one or two rows of silica cells. The elements make a regular pattern. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs.

Long cells are deeply wavy on both surfaces.

56. Heteropogon contortus Roem. & Schultz

The abaxial surface of the leaf has swollen hairs and stomata alternating in the same row and two to four rows of these elements to one or two rows of silica cells with pointed clavate hairs. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs. Stomata are abundant on both surfaces.

Long cells are deeply wavy on both surfaces.

57. Hyparrhenia chysargyrea

The abaxial surface has swollen hairs and stomata alternating in the same row and one or two of these to one or two rows of silica cells with swollen hairs. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs, swollen hairs and stomata.

Long cells are deeply wavy on both surfaces.

58. Hyparrhenia confinis

The abaxial surface has stomata and bulbous hairs alternating in the same row and one or more rows of these elements to one row of silica cells with swollen hairs. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs and swollen hairs.

Long cells are shallowly wavy on the marginal portion of the leaf on both surfaces.

59. Hyparrhenia cymbaria (L.) Stapf

The abaxial surface has stomata and small swollen hairs alternating in the same row and one or two rows of these to one row of silica cells with large clavate hairs. The silica cells are dumbbell-shaped. Both surfaces have bicellular hairs, swollen hairs, and bulbous hairs.

Long cells are shallowly wavy on both surfaces.

60. Hyparrhenia diplandra

The abaxial surface of the leaf has stomata and swollen hairs alternating in the same row, and two rows of these elements to one row of silica cells. The cilica cells are dumbbell-shaped or cruciate. Both surfaces have stomata, ovate hairs, swollen hairs, and bicellular hairs.

Long cells are deeply wavy on both surfaces.

The adaxial surface is prominently undulate.

61. Hyparrhenia edulis (Greenhouse)

The abaxial surface has silica cells and bulbous hairs alternating in the same row, and one row of these elements to one row of stomata with swollen hairs. Silica cells are dumbbell-shaped. Both surfaces of the leaf have bicellular hairs and swollen hairs, while stomata are on the abaxial surface only.

Long cells are shallowly wavy on both surfaces.

The epidermal pattern is quite uniform.

62. Hyparrhenia edulis (Nursery)

The abaxial surface has silica cells and bulbous hairs alternating in the same row, and one row of these elements to one or two rows of stomata and swollen hairs alternating the same row. The silica cells are dumbbell-shaped. Both surfaces have long cushion hairs, swollen hairs, and bicellular hairs. The adaxial surface has many more cushion hairs than the lower surface.

Long cells are deeply wavy on both surfaces.

The adaxial surface contains a few stomata in comparison to Hyparrhenia edulis grown in the greenhouse in which they are lacking on the adaxial surface.

63. Hyparrhenia familiaris

The abaxial surface has stomata and swollen hairs alternating in the same row, and one to six rows of these elements to one or two rows of silica cells. The silica cells are dumbbell-shaped. Both surfaces have many large cushion hairs, swollen hairs, and bicellular hairs.

The long cells are shallowly wavy on both surfaces.

The cork cells are quadrate in shape.

64. Hyparrhenia hirta (L.) Stapf

The abaxial surface has stomata and swollen hairs alternating in the same row and one row of these elements to one row of silica cells with swollen hairs in the same row. The large swollen hairs have prominent horizontal striae.

The silica cells are nearly dumbbell-shaped.

Bicellular hairs occur on both surfaces.

Long cells are deeply wavy on both surfaces of the marginal portion.

65. Hyparrhenia rufa (Madagascar)

The abaxial surface has two to four rows of stomata alternating with two rows of silica cells. The silica cells are dumbbell-shaped. Bicellular hairs occur on both surfaces, and swollen hairs on the upper surface.

Long cells are deeply wavy with loops nearly touching on both surfaces.

Short cells are deeply wavy between the long cells.

Stomata are lacking on the adaxial surface.

66. Hyparrhenia rufa (Ness) Stapf (Belgian Congo)

The abaxial surface has stomata and swollen hairs alternating in the same row, and two rows of these elements to one to three rows of silica cells with bulbous hairs in the same row.

The silica cells are dumbbell-shaped and double-bladed-axe-shaped, or sometimes cruciate. Bicellular hairs occur on both surfaces.

Long cells are deeply wavy on the marginal portion.

Conspicuous light rows mark the silica-bulbous hair rows.

Stomata occur on both surfaces.

The epidermal pattern is different than Hyparrhenia rufa from Madagascar.

67. Hyparrhenia ruprechii

The abaxial surface has stomata and swollen hairs alternating in the same row, and two rows of these elements to one row of silica cells with small cushion hairs or bulbous hairs in the same row. The silica cells are dumbbell-shaped.

The adaxial surface has silica cells and cushion hairs alternating in the same row.

The Long cells are deeply wavy on both surfaces.

Stomata occur on both surfaces.

Papillae vary greatly in size and shape and are very numerous, usually in distinct rows on the long cells in the middle of the cells.

68. Hyparrhenia welwitschii

The abaxial surface has stomata and swollen hairs alternating in the same row, and one row of these elements to three rows of silica cells with bulbous clavate hairs in the same row. The silica cells are nearly dumbbell-shaped, bicellular hairs and swollen hairs occur on both surfaces.

Long cells are deeply wavy on the marginal portion of both surfaces.

Stomata occur on both surfaces.

69. Ischaemum rugosum Salisb.

The abaxial surface has papillate and swollen hairs, whereas the adaxial surface has ovate hairs. The silica cells are above the vein portion of both surfaces. Bicellular hairs are few, and cushion hairs are on both surfaces.

The long cells are deeply wavy in the abaxial epidermis.

The subsidiary cells have a small papillae at each end. This is rarely found in other members of the Andropogoneae investigated.

Papillae are very numerous, small, and uniform on the abaxial surface and are nearly absent on the adaxial surface.

70. Ischaemum sp. (May be Isolaema)

The abaxial surface of the leaf has many swollen hairs, papillate hairs, and cushion hairs, the latter very large.

The silica cells are above the vein portion of the adaxial surface and are hardly found in the abaxial surface.

The silica cells are double-bladed-axe shaped. Bicellular hairs occur on the upper surface.

The long cells are shallowly wavy on the adaxial surface.

The guard cells of the stomata are papillate in the abaxial epidermis.

Two or more stomatal rows may alternate with each silica row.

71. Iseilema laxum

The abaxial surface has stomata and swollen hairs alternating in the same row, and one or two rows of these elements to one or two rows of silica cells. The silica cells are dumbbell-shaped.

Bicellular hairs occur on both surfaces of the leaf.

The adaxial surface has large round hairs which are much larger than on the abaxial surface.

The long cells are shallowly wavy on both surfaces.

Stomata occur on both surfaces.

72. Iseilema vaginiflorum

The lower surface has stomata and swollen hairs alternating in the same row and one or two rows of these elements to one or two rows of silica cells. The silica cells are dumbbell-shaped.
Bicellular hairs occur on both surfaces of the leaf.
The upper surface has round hairs.
The long cells are deeply wavy on both surfaces.
Stomata occur on both surfaces.

73. Lasiurus hirsutus (Forsk) Boiss.

The abaxial surface has short cells between the long cells and a few dumbbell-shaped silica cells. Often two short cells occur together. The silica cells are not abundant.
Bicellular hairs and stomata occur on both surfaces.
Long cells are deeply wavy on both surfaces and the adaxial surface of the epidermis is undulate. The silica cells are nearly dumbbell-shaped, but are usually quadrate and occur together with a cork cell.

74. Miscanthidum junceum (Stapf) Stapf

The abaxial surface has short cruciate, dumbbell-shaped, or double-bladed axe-shaped silica cells between the long cells.
The adaxial surface has a few macrohairs, but no cushion hairs could be found, and both surfaces have bicellular hairs and stomata.
Long cells are deeply wavy, appearing like continuous loops on both surfaces.

75. Miscanthus sinensis Anderss.

The abaxial surface has stomata and swollen hairs alternating in the same row, and two or three rows of these to one row of silica cells. The silica cells are nearly dumbbell-shaped and above the vein portion. The adaxial surface has silica cell rows clearly above the vein portion. Macro-hairs (cushions are lacking or not well developed), many swollen hairs, lanceolate hairs and papillate hairs occur on the abaxial surface. The adaxial surface has large swollen hairs and small bicellular hairs.
The long cells are shallowly wavy on both surfaces, and the abaxial surface is undulate.

76. Pogonatherum paniceum (Lam.) Hack.

The abaxial surface has many short papillae and a few stomata. The adaxial surface has a row of silica cells between the rows of papillae and bicellular hairs. The silica cells are dumbbell-shaped and nodulose.
Long cells are shallowly wavy on both surfaces.

77. Rottbellia exaltata L.f

The abaxial surface has one to three rows of stomata alternating with one to four rows of silica cells. The vein portion has four distinct rows of silica cells. The adaxial surface has silica cells and spindle shaped hairs alternating in the same row. Cushion hairs occur on the adaxial surface. The silica cells are dumbbell-shaped and nodulose.

The long cells are deeply wavy on both surfaces.

Stomata occur on both surfaces.

78. Schizachyrium jeffreysii (Hack.) Stapf

The abaxial surface has one to two rows of stomata alternating with one row of silica cells. The silica cells are dumbbell-shaped. In the adaxial surface the silica cells are very distinct and usually occur in single rows, and a few bicellular hairs and small bulbous hairs are present.

Long cells are deeply wavy on both surfaces of the marginal portions of the leaf. The pattern of the abaxial epidermis is very characteristic in that it shows large bulbous cells alternating with the stomata in the same row. The nearly uniform alternation of stomata and silic cells in a one to one row ratio is quite distinct.

79. Schizachyriumlittoralis

The abaxial surface has a row of silica cells and one to two rows of stomata alternating. The adaxial surface has a few silica cells, spindle-shaped hairs, and bulbous hairs. A few bicellular hairs are present. The lower surface has small bicellular hairs.

Long cells are deeply wavy on both surfaces.

Stomata are rare on the adaxial surface and occur mainly in a single row near the leaf margin.

80. Sorghum aethiopicum

The abaxial surface has three or four distinct rows of silica cells on some veings. Six to seven rows of stomata alternate with each row of silica cells. This is a very large number. The silica cells are dumbbell-shaped. Bicellular hairs occur on both surfaces of the leaf and are few in number. A abaxial surface has many convex cells. Stomata occur on both surfaces. The long cells are deeply wavy on the upper surface. Stomata are almost as abundant on the adaxial surface as on the abaxial.

81. Sorghum halepense (L.) Pers.

The abaxial surface has one to three rows of silica cells alternating with two to five or more rows of stomata. The silica cells are almost dumbbell-shaped. Bicellular hairs are very few on both surfaces, and bulbous hairs are few on the adaxial surface.

The long cells are deeply wavy.

Stomata occur on both surfaces.

82. Sorghum halepense (L.) Pers. (Dehra Dun, India)

The abaxial surface has one to three rows of silica cells alternating with three to five rows of stomata. The silica cells are dumbbell-shaped and nodulose. Both surfaces have a few bicellular hairs and the adaxial surface has a few swollen hairs.

The long cells are deeply wavy on both surfaces.

The adaxial surface of the epidermis is undulate.

Stomata occur on both surfaces.

83. Sorghum halepense (L.) Pers. (India)

The abaxial surface has one to three rows of silica cells alternating with several rows of stomata. The silica cells are dumbbell-shaped.

A few bicellular hairs and bulbous hairs occur on both surfaces of the leaf.

The long cells are deeply wavy on both surfaces.

Stomata occur on both surfaces.

Epidermal cells appear larger than the collection from Dehra Dun, India.

(Key according to abaxial surface)

A. Bicellular hairs present.

B. Silica cells dumbbell-shaped.

C. Cushion hairs or macrohairs present.

D. Papillae present.

E. Macrohairs present.

F. Papillae dense - *Miscanthus sinensis* (75)

FF. Papillae sparse - *Hyparrhenia edulis* (61)

EE. Cushion hairs present.

F. Guard cells papillate - *Ischaemum rugosum* (69)

G. Papillae small

GG. Papillae large -*Ischaemum* sp.(may be Isolaema) (70)

FF. Guard cells not papillate.

G. Long cells shallowly wavy.

H. Stomata alternating with swollen hairs in the same row.

I. Silica cells alternating with long bicellular hairs or cushion hairs - *Capillipedium parviflorum* (32)

II. Not as above

J. Silica cells only dumbbell-shaped.

K. Epidermal elements large-*Bothriochloa venusta* (31)

KK. Epidermal elements small-*Bothriochloa radicans* (29)

JJ. Silica cells both dumbbell-shaped and H-shaped.

K. Many trichomes on abaxial surface - *Andropogon pseudapricus* (9)

KK. Few trichomes on abaxial surface - *Andropogon distachyus*. (3)

HH. Stomata without alternating swollen hairs in same row - Andropogon gayanus. (5)

GG. Long cell deeply wavy

H. Silica cells alternating with cushion hairs or bulbous hairs.

I. Stomata alternating with swollen hairs in the same row - Hyparrhenia ruprechii (67)

II. Stomata alternating with papillae in the same row Bothriochloa ischaemum (Formosa) (24)

HH. Silica cells not alternating with cushion hairs or bulbous hairs.

I. Silica cells alternate with some trichomes in the same row.

J. Silica cells usually alternating with swollen hairs in the same row -Dichanthium papillosum (48)

JJ. Silica cells alternating with ovate hairs in the same row- Bothriochloa intermedia (India) (18)

II. Silica cells not alternating with trichomes in the same row.

J. Silica cells dumbbell-shaped only - Bothriochloa ischaemum (23)

JJ. Silica cells dumbbell-shaped or some nodulose.

K. Stomata alternating with swollen hairs in the same row - Bothriochloa pertusa (27)

KK. Stomata alternating with ovate papillae in the same row - Bothriochloa insculpta (17)

DD. Papillae absent.

E. Long cells shallowly wavy.

F. Silica cells and some swollen hairs in the same row.

G. Stomata alternating with swollen hairs in the same row - Euclasta condylotricha (54)

GG. Stomata not alternating with swollen hairs in the same row - Andropogon lateralis (8)

FF. Silica cells and some cork cells in the same row - Hyparrhenia familiaris (63)

EE. Long cells deeply wavy.

F. Silica cells alternating with trichomes in the same row - Dichanthium sericeum (49)

FF. Silica cells without alternating trichomes.

G. Silica cells dumbbell-shaped or some nodulose - Cleistachne sorghoides (36)

GG. Silica cells cruciate or double-blaced axe-shaped. Miscanthidium junceum (74)

I. Pointed bulbous hairs abundant - Diectomis Kunth (42)

II. Pointed bulbous hairs few - Hyparrhenia edulis (62)

GG. Silica cells without alternating trichomes in the same row - Andropogon saccharoides (10)

CC. Cushion hairs or macrohairs absent.

D. Papillae present.

E. Long cells shallowly wavy.

F. Silica cells dumbbell-shaped or cruciate - Bothriochloa insculpta (16)

FF. Silica cells dumbbell-shaped or nodulose - Pogonatherum paniceum (76)

EE. Long cells deeply wavy.

F. Silica cells with some trichomes in the same row.

G. Stomata alternating with swollen hairs or large bicellular hairs in the same row.

H. Large swollen hairs abundant and some silica cells nodulose - Bothriochloa radicans (28)

HH. Not as above, and long cells much narrower - Capillipedium spicigera (33)

GG. Stomata alternating with papillae in the same row.

H. Silica cells and some large ovate hairs in the same row - Andropogon gabonensis (4)

HH. Silica cells and some bulbous hairs in the same row.

I. Papillae abundant - Bothriochloa decipiens (14)

II. Papillae not abundant - Andropogon spathiflorus (11)

FF. Silica cells without some trichomes in the same row.

G. Silica cells dumbbell-shaped only.

H. Stomata alternating with clavate hairs in the same row - Bothriochloa intermedia (Calcutta) (22)

HH. Stomata alternating with swollen hairs in the same Bothriochloa intermedia (Australia) (20)

GG. Silica cells dumbbell-shaped or nodulose.

H. Silica cells abundant in each row and nodulose - Bothriochloa saccharoides (30)

HH. Silica cells few in each row and nodulose - Bothriochloa intermedia (Delhi) (21)

DD. Papillae absent.

E. Long cells shallowly wavy.

F. Silica cells dumbbell-shaped only.

G. Silica cells alternating with large clavate hairs - Hyparrhenia cymbaria (59)

GG. Silica cells alternating with bulbous hairs in the same row.

H. Large swollen dichotomous pyriform hairs present - Bothriochloa erianthoides (26)

HH. Large swollen hairs absent.

I. Small round hairs present - Iseilema laxum (71)

II. Large round hairs present-Andropogon barbinodis (1)

FF. Silica cells of various shapes.

G. Silica cells dumbbell-shaped or nodulose - *Dichanthium annulatum* (43)

GG. Silica cells dumbbell-shaped or cruciate.

H. Several silica cells alternating with lanceolate hairs in the same row - *Cymbopogon excavatus* (38)

HH. Silica cells without alternating trichomes - *Cymbopogon sp.* (41)

EE. Long cells deeply wavy.

F. Stomata alternating with trichomes in the same row.

G. Silica cells dumbbell-shaped only.

H. Stomata alternating with bulbous hairs in the same row - *Hyparrhenia confinis* (58)

HH. Stomata alternating with swollen hairs in the same row.

I. Silica cells alternating with swollen hairs in the same row.

J. Pointed swollen hairs present.

K. Adaxial surface undulate - *Hyparrhenia hirta* (64)

KK. Adaxial surface nearly plain - *Erianthus longisetosus* (50)

JJ. Pointed swollen hairs absent *Hyparrhenia chrysargyrea* (57)

II. Silica cells alternating with clavate or bulbous hairs in the same row.

J. Stomata alternating with swollen hairs in the same row.

K. Small trichomes present.

L. Round hairs present - *Iseilema vaginiflorum* (72)

LL. Not as above - *Heteropogon contortus* (55) (56)

KK. Large trichomes present - Hyparrhenia welwitschii (68)

JJ. Stomata alternating with bulbous hairs in the same row.

K. Large bulbous hairs present - Schizachyrium jeffreysii (78)

KK. Small bulbous hairs present - Schizachyrium littorlais (79)

GG. Silica cells various, dumbbell-shaped or otherwise.

H. Silica cells of nodulose form.

I. Bulbous clavate hairs present.

J. Adaxial surface with large bulbous hairs - Dichanthium caricosum (45)

JJ. Adaxial surface with small bulbous hairs - Dichanthium caricosum var. media (47)

II. Spindle shaped, clavate hairs present - Dichanthium caricosum (46)

HH. Silica cells double-bladed-axe-shaped or cruciate.

I. Swollen hairs with concentric banded marking - Hyparrhenia diplandra (60)

II. Swollen hairs without banded marking Hyparrhenia rufa (Belgian Congo) (66)

FF. Stomata without alternating trichomes in the same row.

G. Stomata alternating with convex epidermal cells in the same row - Andropogon ternarius (12)

GG. Stomata alternating with plain epidermal cells in the same row.

H. Silica cells dumbbell-shaped.

I. Silica cells alternating with cork cells in the same row.

J. Bicellular hairs and bulbous or swollen hairs present.

K. Bulbous hairs present.

L. Long cells wide - Sorghum halpense (India) (83)

LL. Long cells narrower than above - Bothriochloa intermedia (P. I.) (19)

KK. Swollen hairs present.

L. Silica cells dumbell-shaped only Bothriochloa glabra (15)

LL. Silica cells cruciate shaped.

M. Long cells irregular and slightly raised - Sorghum halepense (Israel) (81)

MM. Long cells regular and nearly plane - Hyparrhenia rufa (Madagascar) (65)

JJ. Bicellular hairs only present.

K. Silica cells not abundant - Lasiurus hirsutus (73)

KK. Silica cells few.

L. Convex cells occur between stomata in the same row - Cymbopogon martinii (40)

LL. Convex cells lacking between stomata in the same row - Sorghum aethiopicum (80)

II. Silica cells with some trichomes in the same row.

J. Ovate or spindle-shaped hairs present.

K. A group of silica cells alternating with single ovate hairs - Andropogon gerardi (6)

KK. Silica cells alternating with pointed spindle shaped hairs - Andropogon hallii (7)

JJ. Bulbous hairs present.

K. Silica cells alternating with either bulbous or bicellular hairs in the same row - Chrysopogon montanus (35)

KK. Several silica cells alternating with bulbous hairs - Dichanthium aristatum (44)

HH. Silica cells double-bladed axe-shaped - *Erianthus sp.* (52)

BB. Silica cells various but not dumbbell-shaped.

C. Silica cells double-bladed axe-shaped or cruciate - *Chrysopogon aucheri* (Ethiopia) (34)

CC. Silica cells nodulose *Sorghum halepense* (Dehra, India) (82)

AA. Bicellular hairs absent.

B. Silica cells dumbbell-shaped only.

C. Cushion hairs present.

D. Stomata alternating with swollen or bulbous hairs in the same row - *Bothriochloa ischaemum* (25)

DD. Stomata alternating with normal cells - *Rottbellia exaltata* (77)

CC. Cushion hairs absent.

D. Trichomes not present - *Cymbopogon bombycinus* (37)

DD. Trichomes present.

E. Swollen hairs present - *Andropogon bicornis* (2)

EE. Rounded swollen hairs and pointed bulbous hairs present - *Eremopogon faveolatus* (53)

BB. Silica cells nodulose, dumbbell-shaped or cruciate.

C. Silica cells nodulose only - *Apluda varia* (13)

CC. Silica cells dumbbell-shaped, nodulore, or cruciate.

D. Stomata alternating with clavate hairs in the same row - *Erianthus ravennae* (51)

DD. Stomata alternating with normal cells in the same row - *Cymbopobon hookeri* (39)

INDEX TO FIGURES

Note: The original magnification of X560 has been preserved in these photos.

Symbols are as follows:

B. - Bulbous hairs

Bi. - Bicellular-microhairs

Co. - Cork cells

C.S. - Cruciate shaped silica cells

Cu. - Cushion hairs

D.a. - Double-bladed axe-shaped silica cells

D.s. - Dumbbell-shaped silica cells

La. - Lanceolate hairs

Ma. - Macrohairs

Ov. - Ovate hairs

Pa. - Papillae

Ro. - Round hairs

S. - Swollen hairs

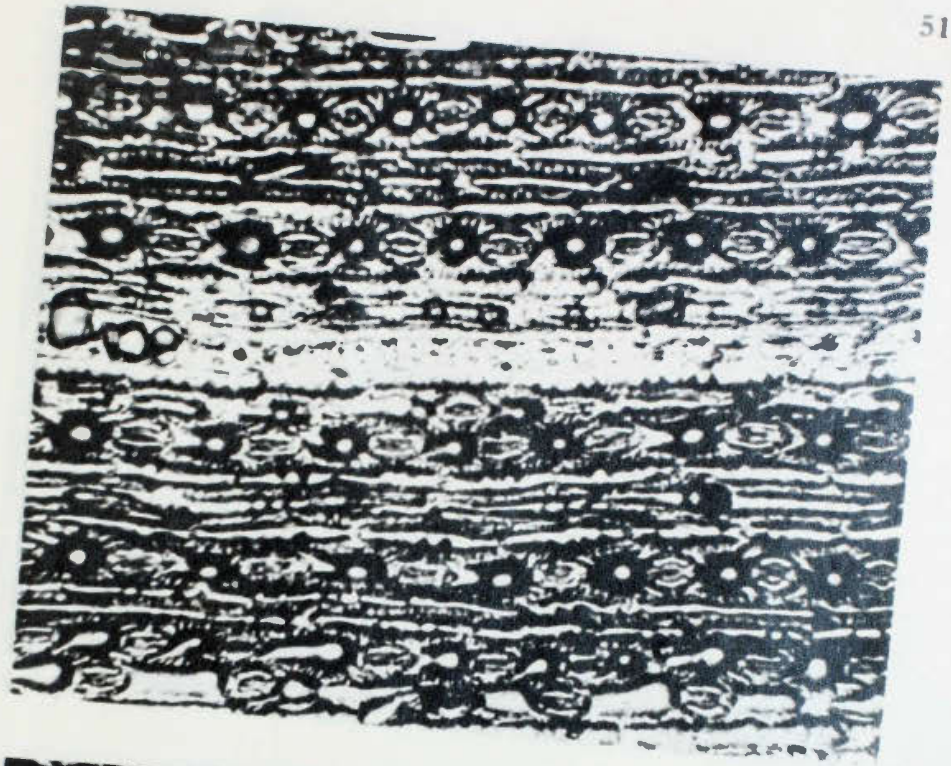
INDEX TO FIGURES

Fig. No.	HCR Acc. No.	Scientific name	Original or Last Known Source
1	8521	Andropogon barbinodis Lag.	Argentina
2	8516	A. bicornis	Brazil
3	8565	A. distachyus L.	Algeria (Type for genus)
4	8564	A. gabonensis	Belgian Congo
5	8517	A. gayanus Kunth	Tanganyika, Africa
6	8519	A. gerardi Vitman	Oklahoma
7	8520	A. hallii Hack.	Wynoka, Oklahoma
8	8514	A. lateralis	Brazil
9	8566	A. pseudapricus Stapf	Belgian Congo
10	8510	A. saccharoides Swartz	Venezuela
11	8515	A. spathiflorus	Brazil
12	8518	A. ternarius Michx	Oklahoma
13	8575	Apluda varia	Dehra Dun, India (6 anthers)
14	8478	Bothriochloa decipiens C. E. Hubb.	Australia
15	8477	B. glabra A. Camus	United Provinces, India via
16	8482	Bothriochloa "insculpta"?	S. Afr.
17	8481	B. insculpta A. Camus	Nairobi, Kenya, Afr.
18	8475	B. intermedia A. Camus	Coimbatore, India
19	8556	B. intermedia A. Camus	P. I.
20	8559	B. intermedia A. Camus	Australia
21	8558	B. intermedia A. Camus	Delhi, India (Hexaploid)

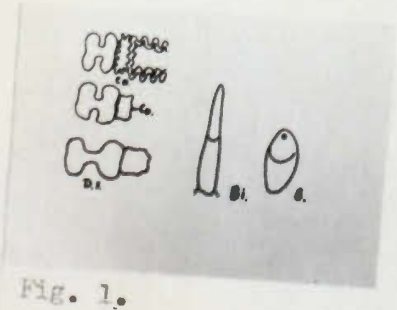
22	8557	B. intermedia A. Camus	Calcutta, India
23	8472	B. ischaemum Keng	Amoy, China, via Woodward, Ok
24	8473	B. ischaemum Keng	Formosa
25	8474	B. ischaemum Keng	Austria
26	8600	B. erianthoides C. E. Hubbard	Australia
27	8480	B. pertusa A. Camus	Ceylon (not flowering)
28	8479	B. radicans A. Camus	Kenya, Afr.
29	8601	B. radicans?	Nairobi, Kenya, Afr.
30	8476	B. saccharoides Rydb.	Glass Mts. Oklahoma
31	8602	B. venusta A. Camus	British Guiana
32	8486	Capillipedium parviflorum Stapf	Kenya Afr. (not flowering)
33	8487	Capillipedium spicigera	Texas
34	8579	Chrysopogon aucheri Stapf	Ethiopia
35	8506	C. montanus Trin.	New Delhi, India
36	8580	Cheistachne sorghoides Benth.	So. Rhodesia
37	8505	Cymbopogon bombycinus Comin.	Australia
38	8504	C. excavatus	So. Rhodesia
39	8577	C. Hookeri	Allahabad, India
40	8595	C. martinii	Punjab, India
41	8576	C. sp.	Ajmer, India (lvs. pungent)
42	8511	Diectomis Kunth	
43	8488	Dichanthium annulatum Stapf	India

44	8522	D. aristatum C. E. Hubbard	So. Africa
45	8492	Dichanthium caricosum A. Camus	
46	8493	C. caricosum	Malay (Deep purple stem)
47	8491	D. caricosum var. media	(not flowering)
48	8489	D. papillosum Stapf	San Antonio, Texas
49	8490	D. Sericeum A. Camus	Australia via San Antonio, Tex
50	8569	Erianthus longisetosus	
51	8484	Erianthus ravennae (l.) Beauv.	
52	8483	Erianthus sp.	
53	8485	Eremopogon faveolatus Stapf	Coimbatore, India
54	8597	Euclasta condylotricha Stapf	
55	8508	Heteropogon contortus	New Delhi, India
56	8509	H. contortus Roem & Schultz	Allahabad, India
57	8591	Hyparrhenia chrysargyrea	Belgian Congo
58	8590	H. confinis	Belgian Congo
59	8589	H. cymbaria (L.) Stapf	Madagascar
60	8561	H. diplandra	Belgian Congo
61	8603	H. edulis	Anglo-Egyp. Sudan (greenhouse)
62	8498	H. edulis	Anglo-Egyp. Sudan (not fl.)
63	8592	H. familiaris	Belgian Congo
64	8563	H. hirta (L.) Stapf	Portugal
65	8499	H. rufa	Madagascar
66	8562	H. rufa (Nees) Stapf	Belgian Congo
67	8594	H. ruprechii	Belgian Congo
68	8593	H. welwitschii	Belgian Congo
69	8573	Ischaemum rugosum Salisb.	Assam, India
70	8496	I. sp. (May be Isolaema)	Mt. Abu, India

71	8574	Iseilema laxum	Assam, India
72	8596	I. vaginiflorum	Canberra, Australia
73	8598	Lasiurus hirsutus (Forsk) Boiss.	W. Sahara; Bein Abbes, Afr.
74	8523	Miscanthidium junceum (Stapf)	So. Rhodesia (Botany Greenhouse
75	8567	Miscanthus sinensis Anderss.	Mt. Fuji, Japan
76	8604	Pogonatherum paniceum (Lam.) Hack.	Japan
77	8497	Rottboellia exaltata L.f	Kruger Nat'l Park, So.Afr.
78	8512	Schizachyrium jeffreysii (Hack.) Stapf	So. Rhodesia, Afrida
79	8513	S. littoralis	So. Texas
80	8588	Sorghum aethiopicum	
81	8584	S. halepense (L.) Pers.	Israel
82	8587	S. halepense (L.) Pers.	Dehra Dun, India
83	8585	S. halepense (L.) Pers.	India

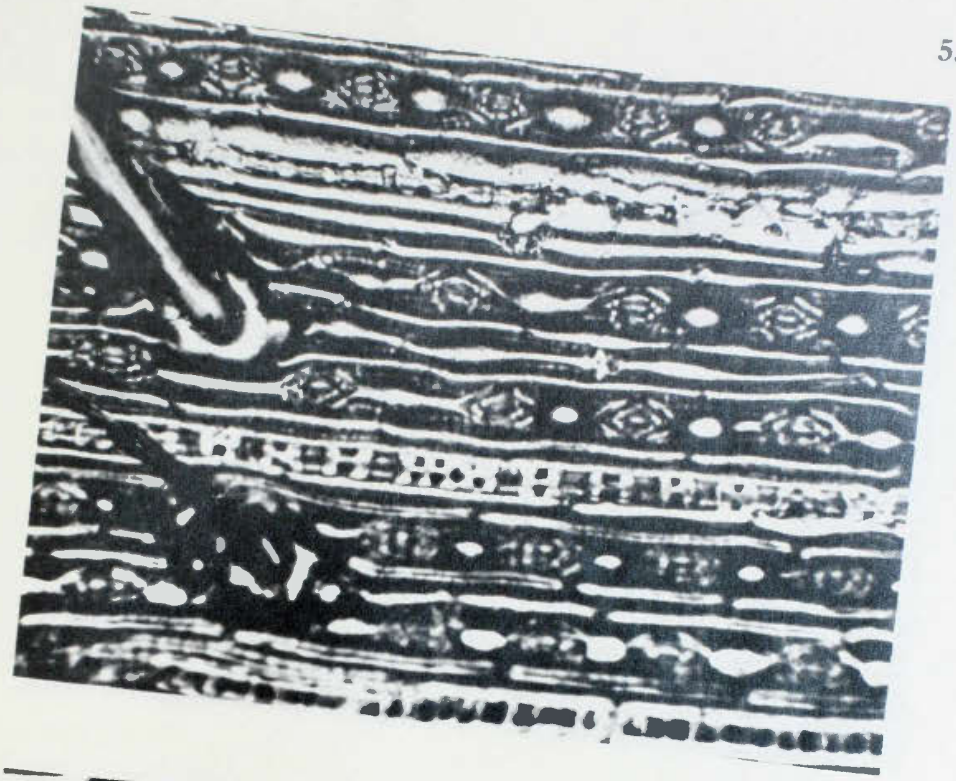


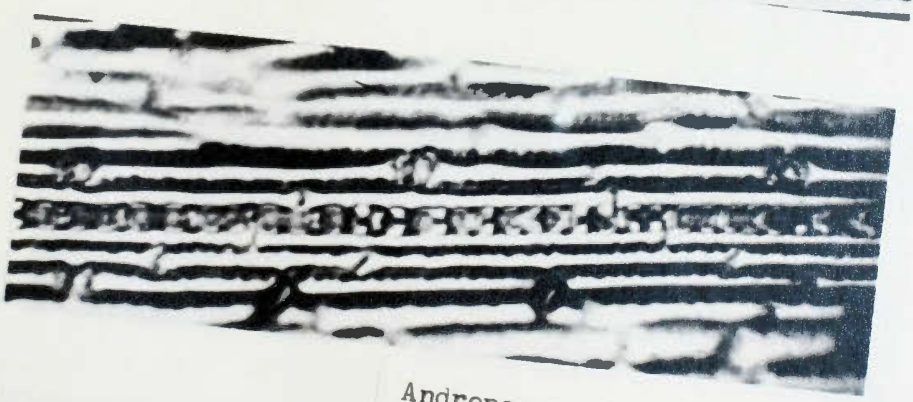
Andropogon barbinodis



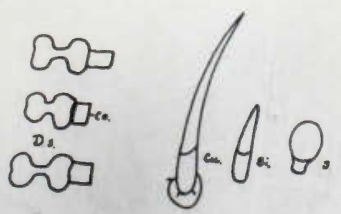
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 1.



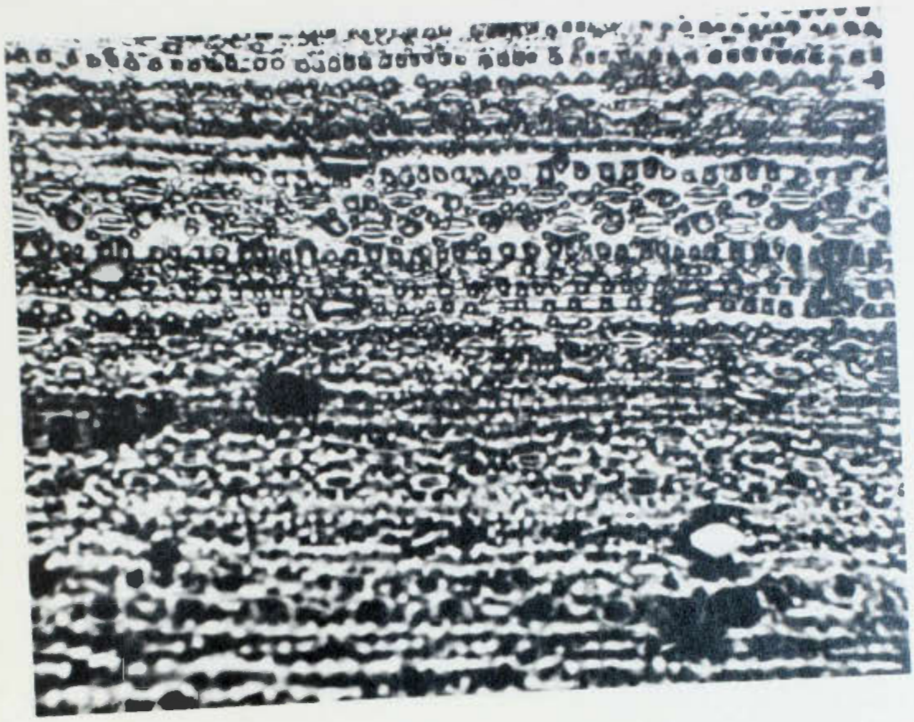


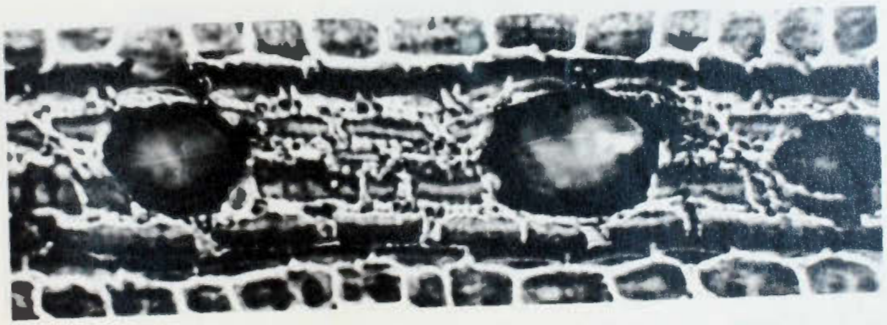
Andropogon distachyus L.



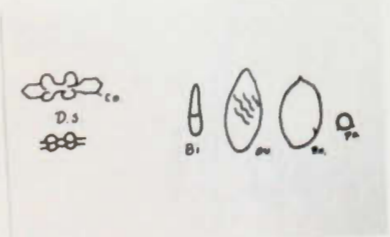
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 3.





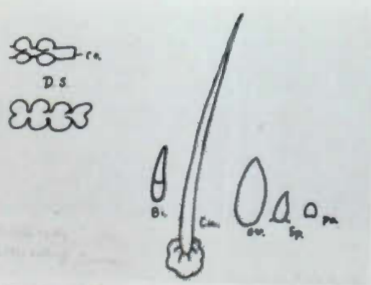
Andropogon gabonensis



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

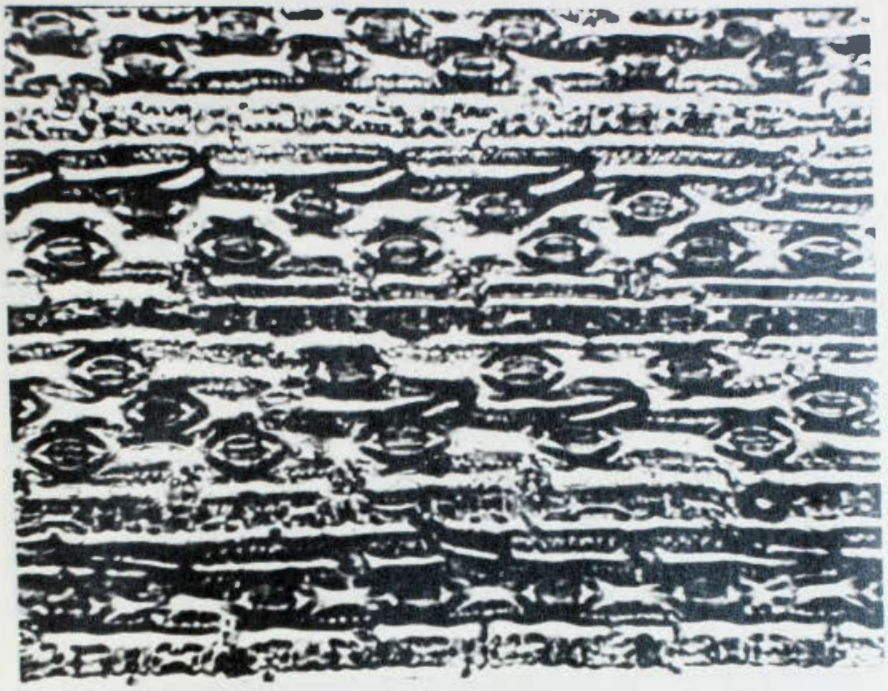
Fig. 4.

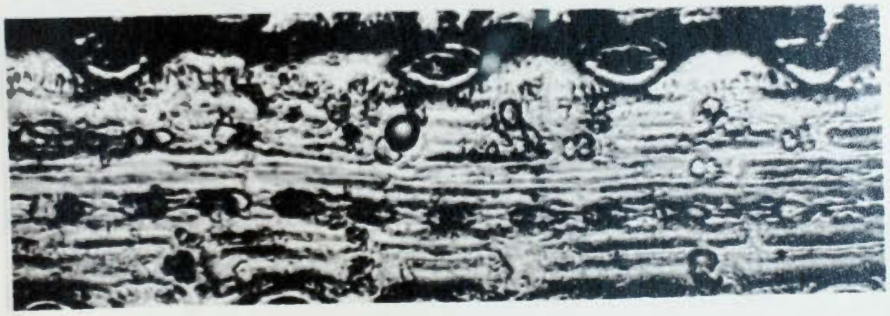
Andropogon gayanus Kunth



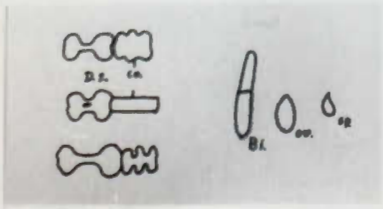
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 5.



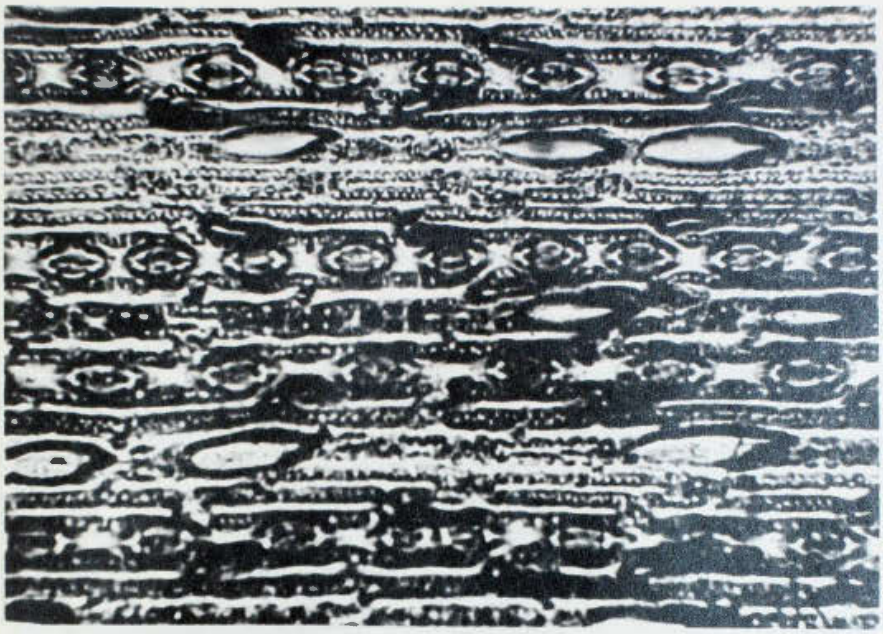


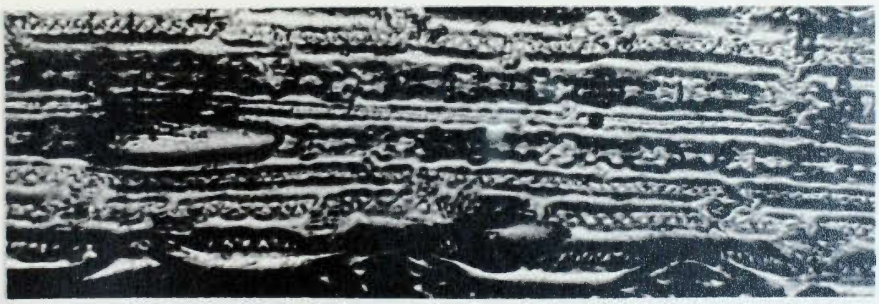
Andropogon gerardi Vitman



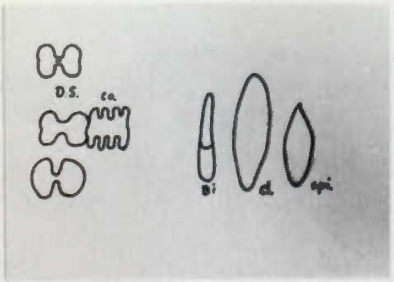
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 6.



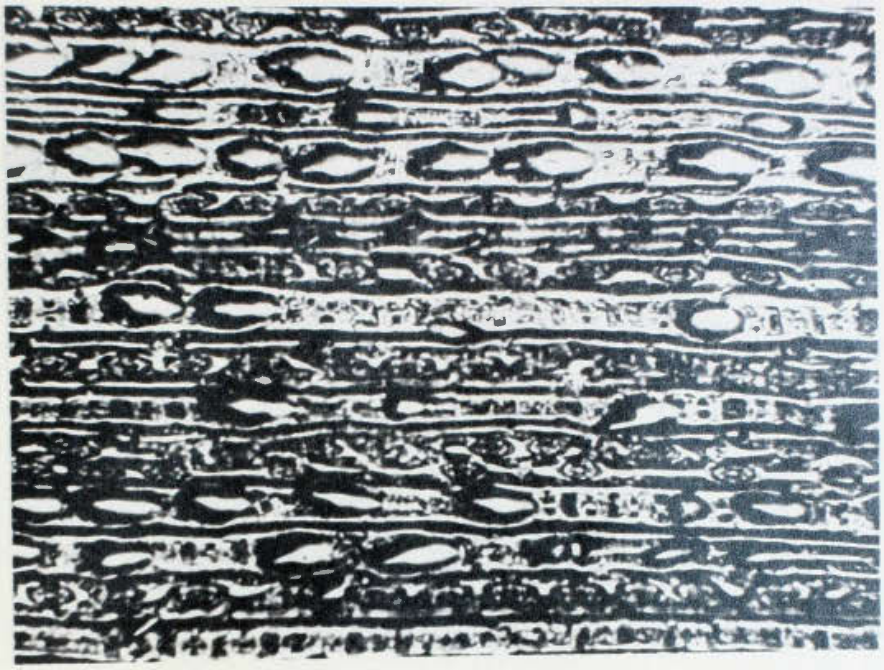


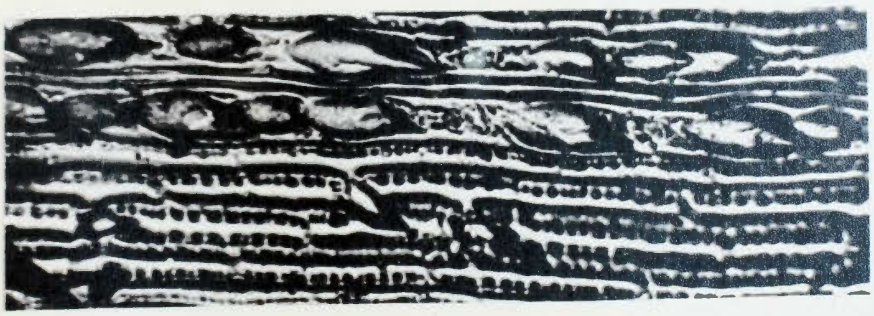
Andropogon hallii Hack.



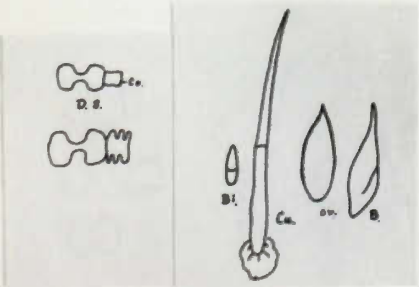
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 7.



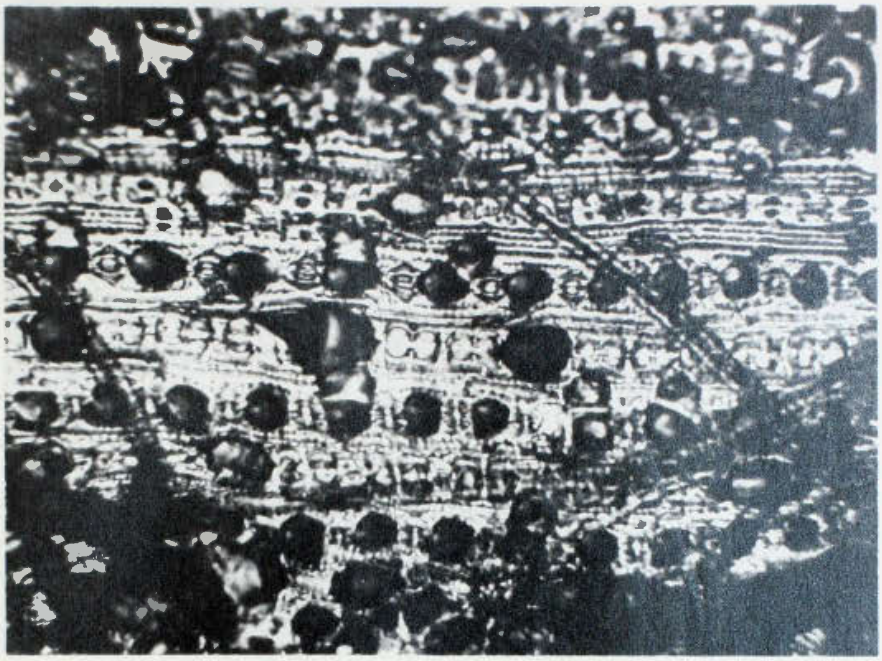


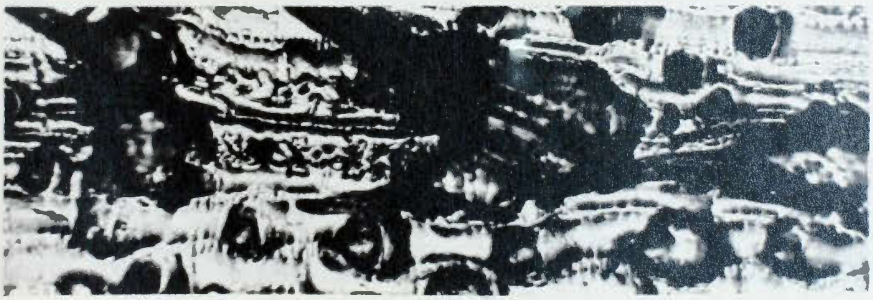
Andropogon lateralis



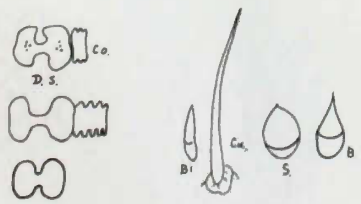
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 8.



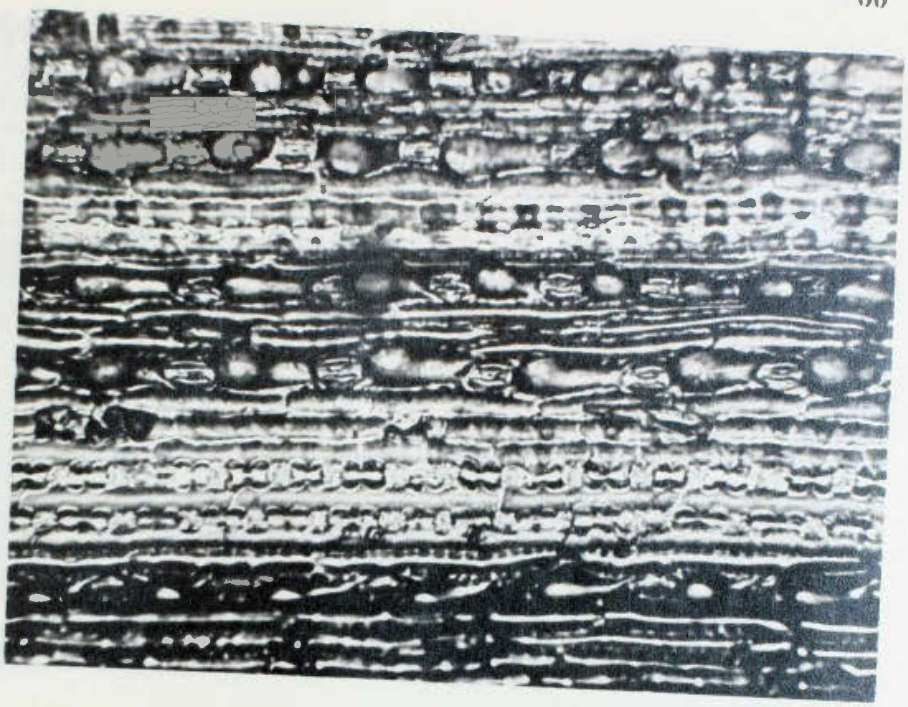


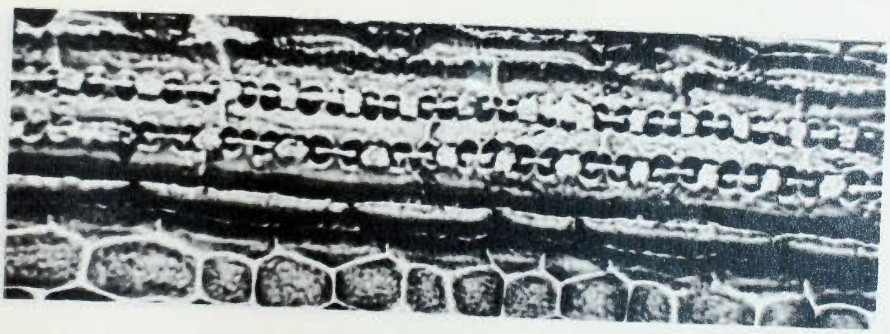
Andropogon pseudapricus Stapf



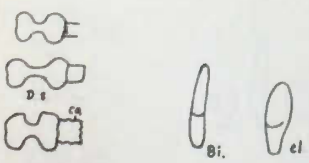
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 9.



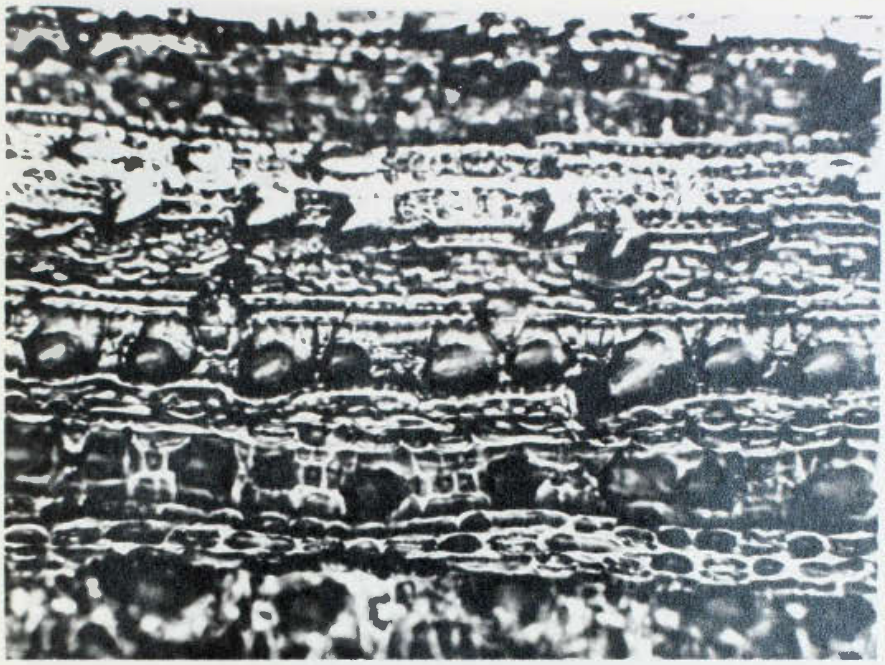


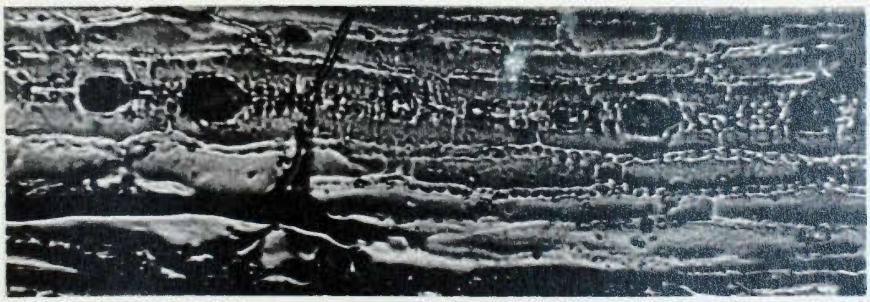
Andropogon saccharoides Swartz



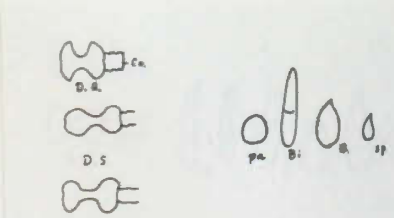
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 10.



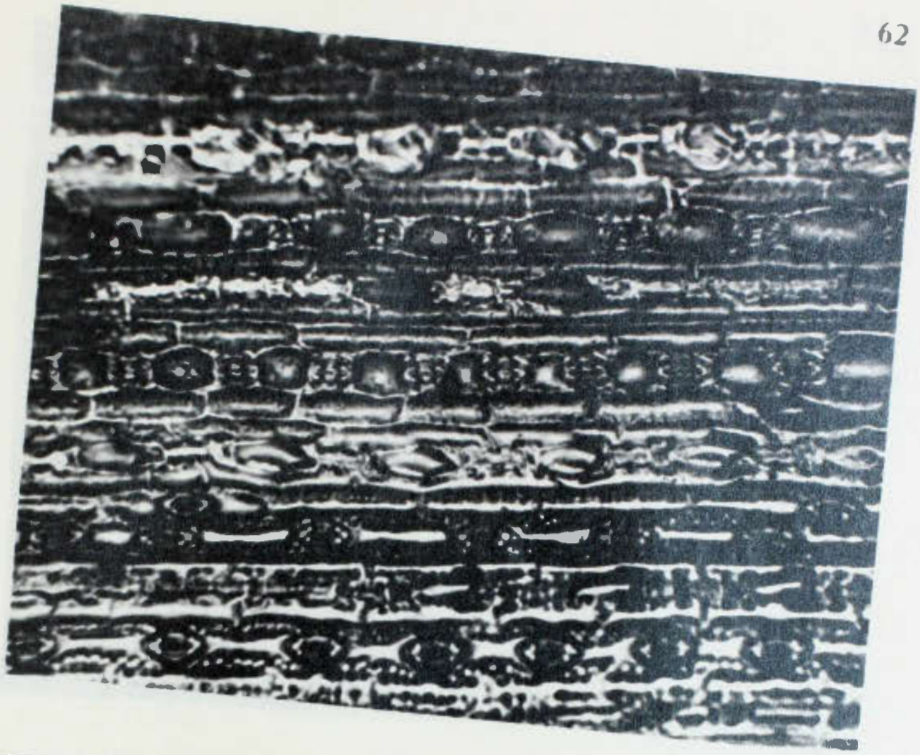


Andropogon spathiflorus

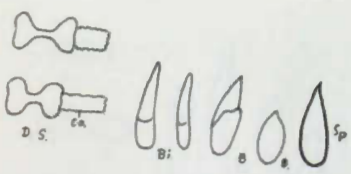


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 11.

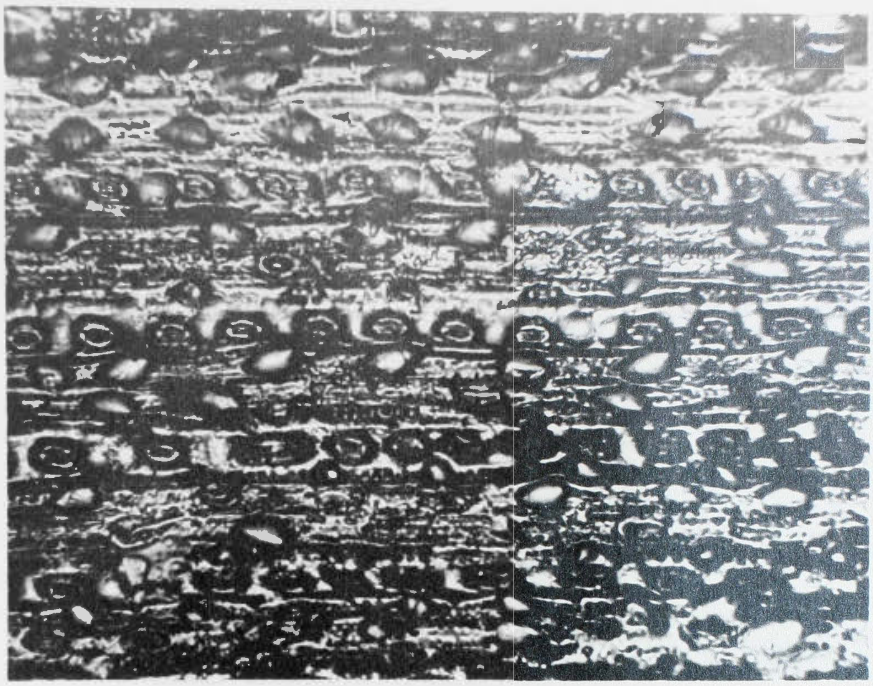


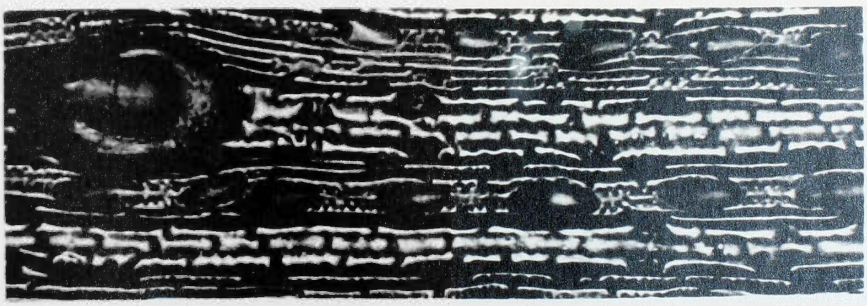
Andropogon ternarius Michx



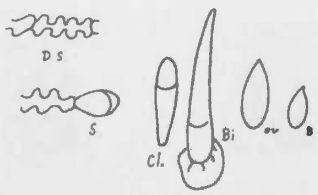
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 12.



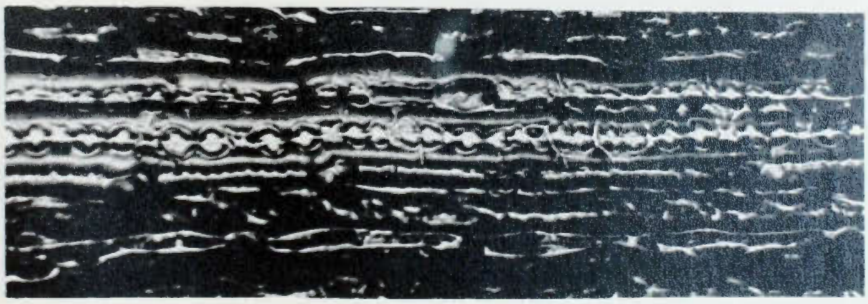


Apluda varia

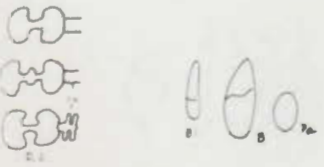


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 13.

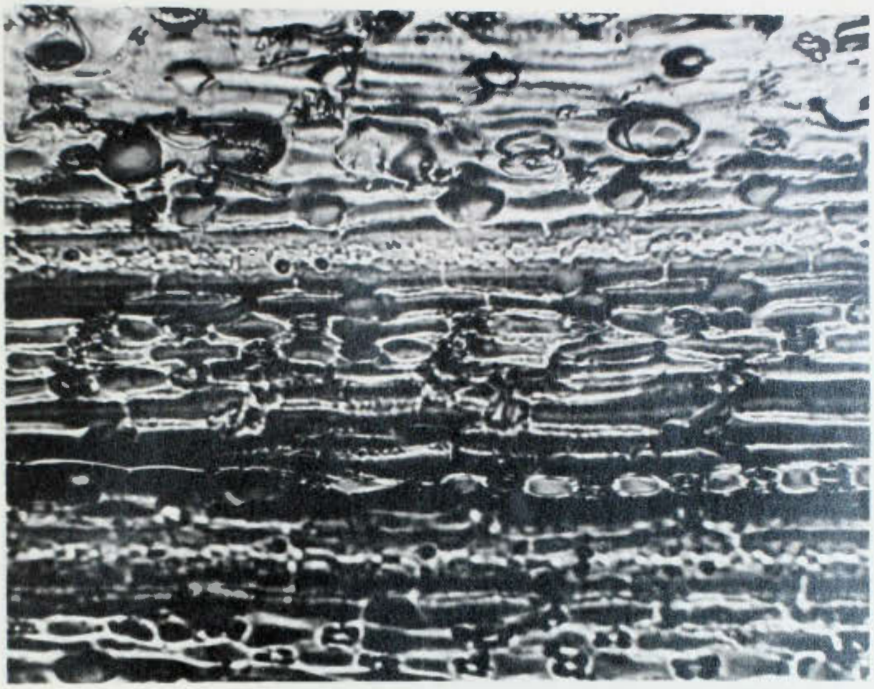


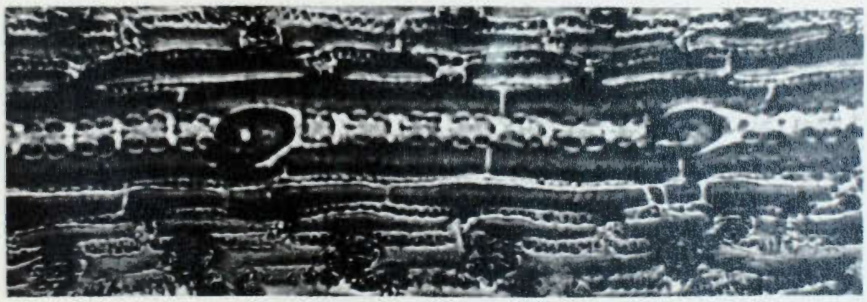
Bothriochloa decipiens C. E. Hubb



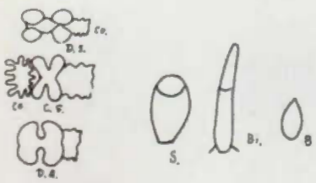
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 14.



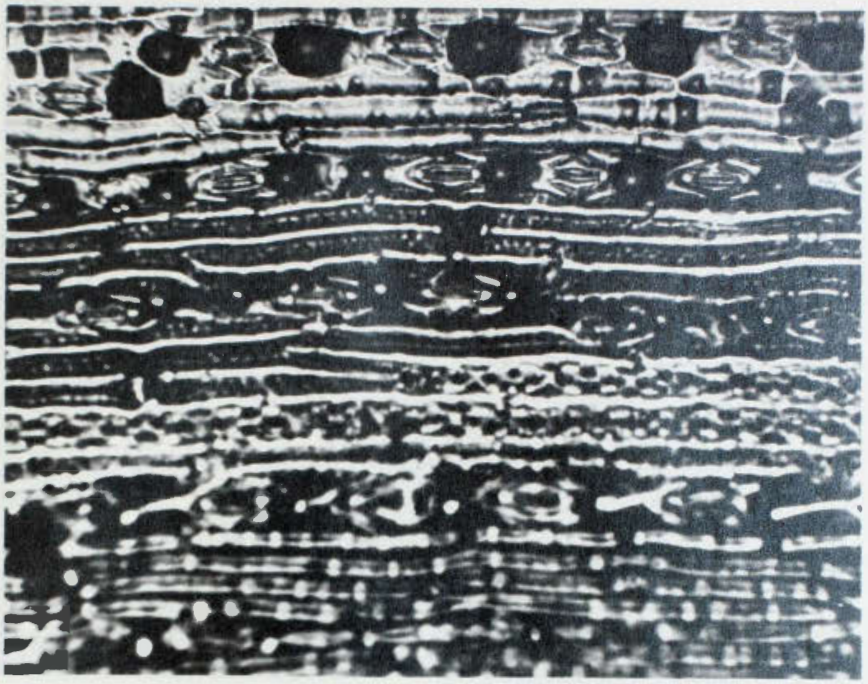


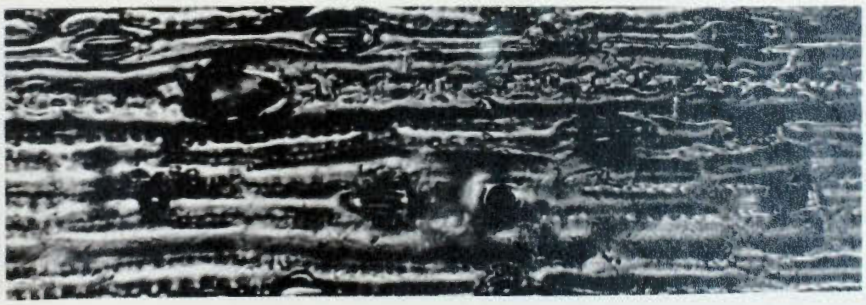
Bothricchloa glabra A. Camus



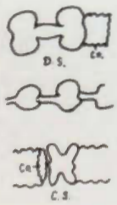
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

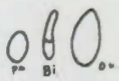
Fig. 15.





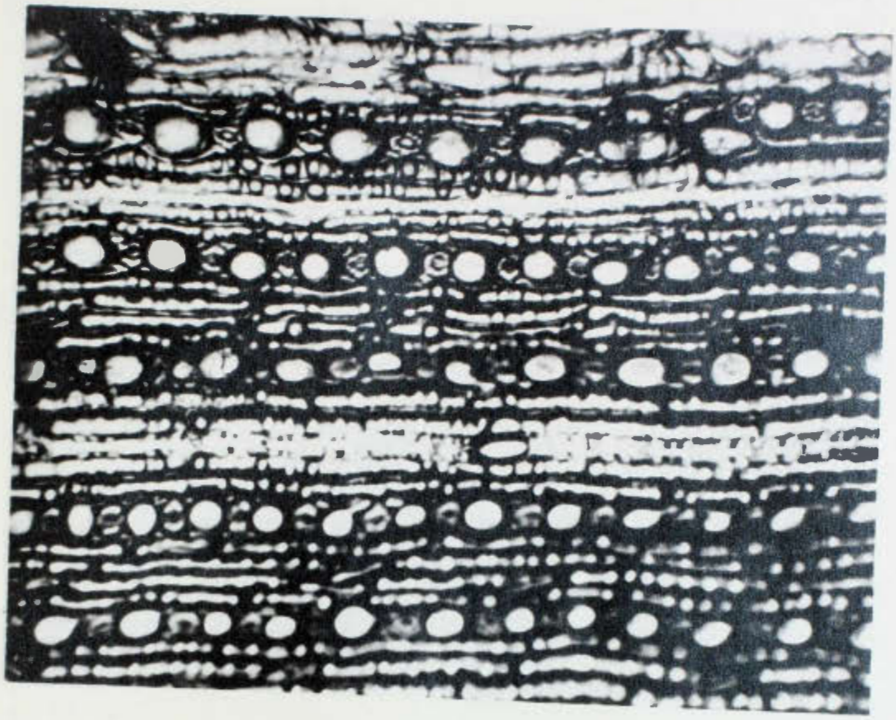
Bothricchloa "insculpta"?

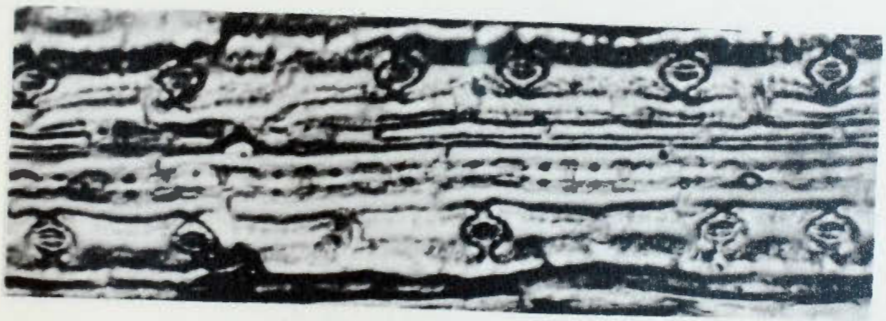




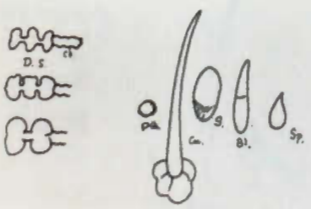
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 16.



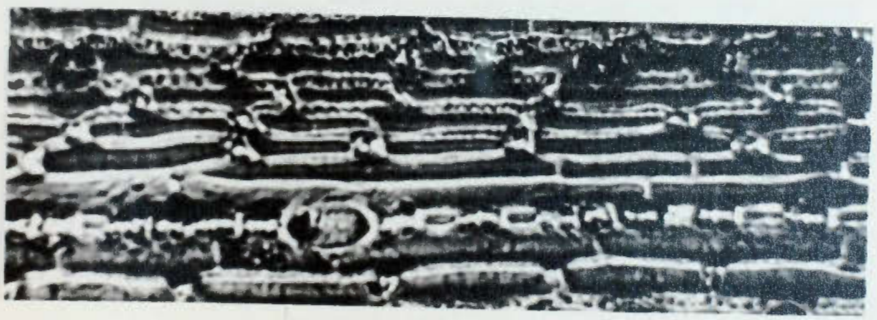


Bothriochloa insculpta A. Camus

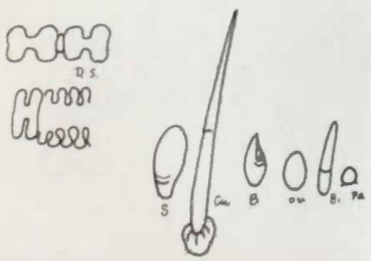


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 17.

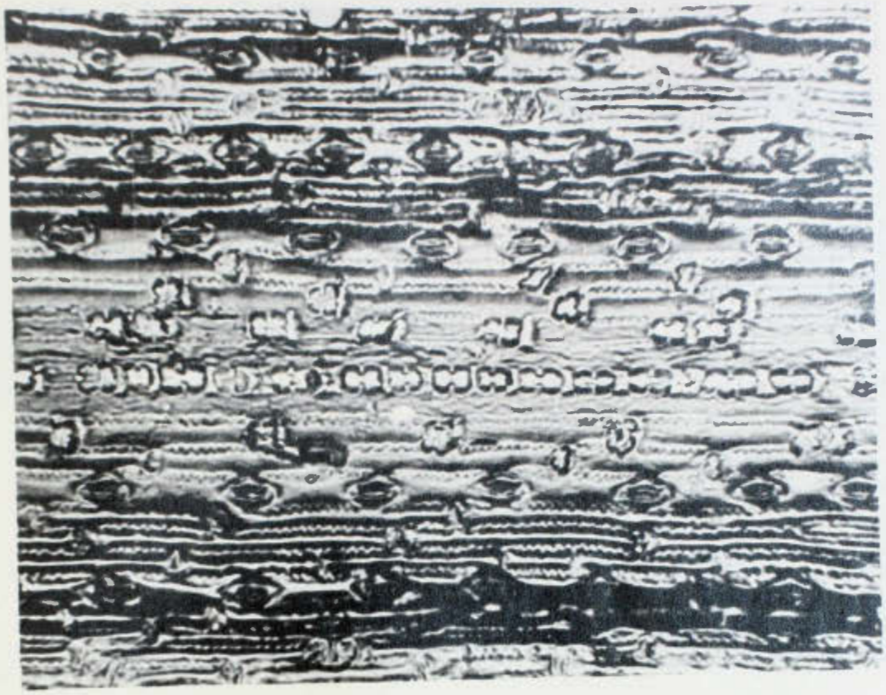


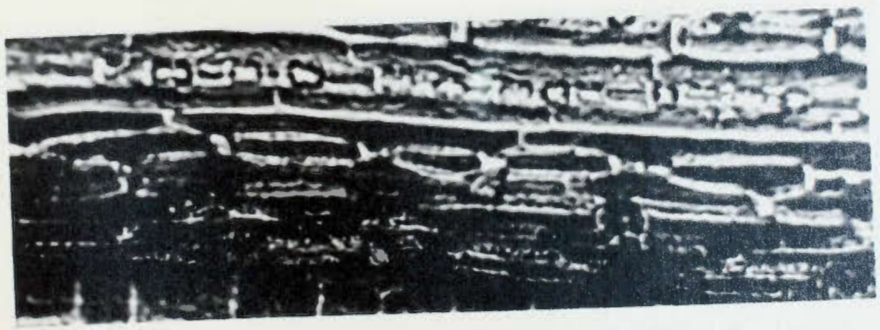
Bothriochloa intermedia A. Camus
Coimbatore, India



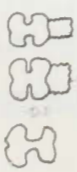
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 18.



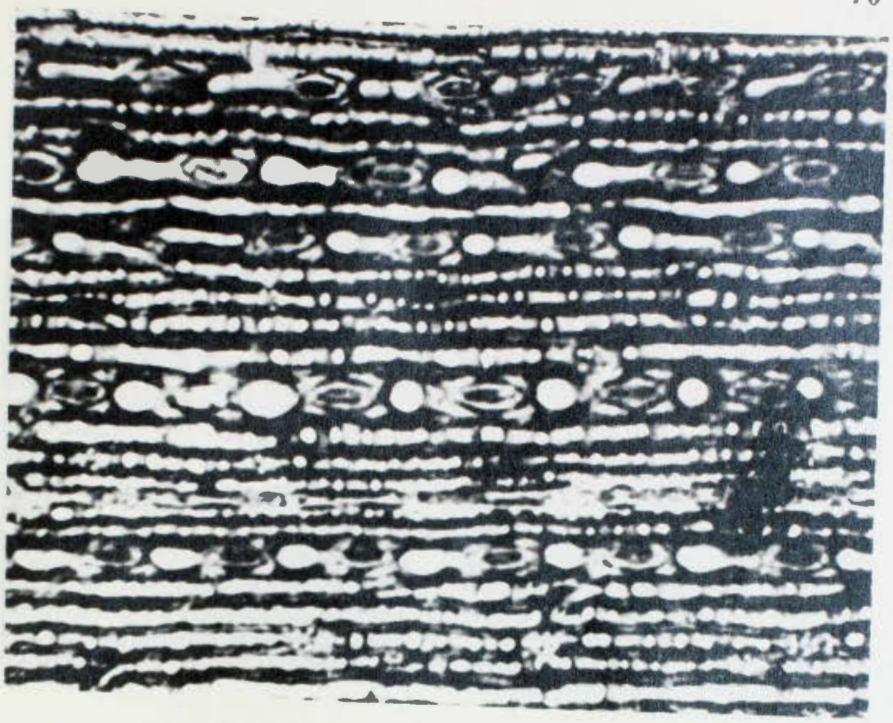


Bothricchloa intermedia A. Camus
P. I.

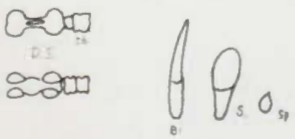


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 19.

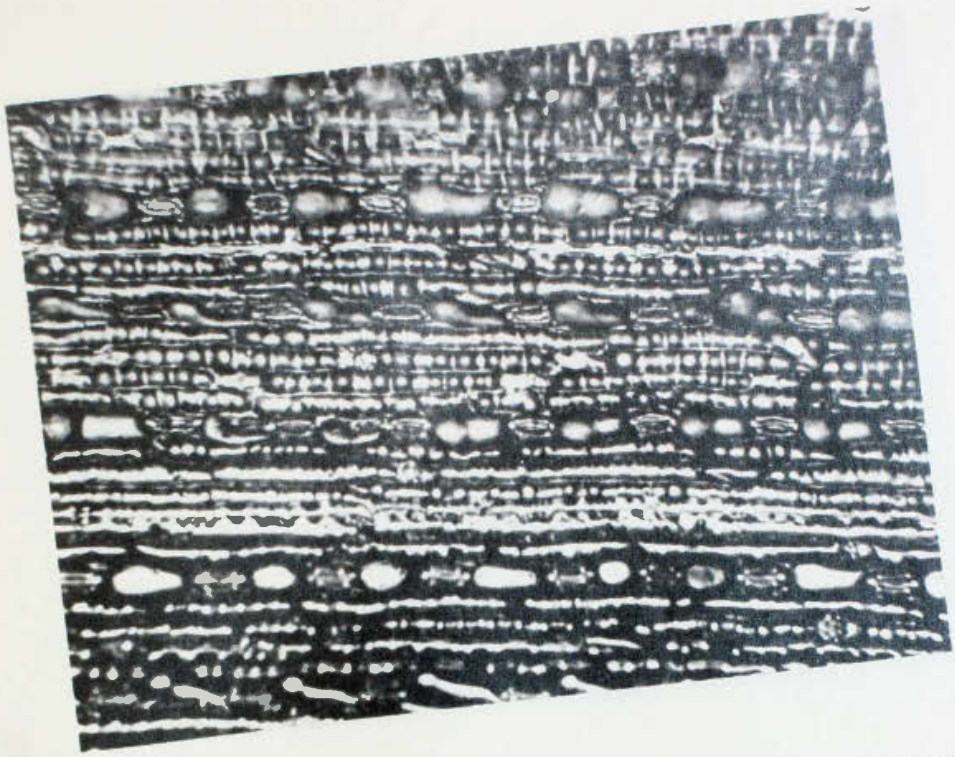


Bothriochloa intermedia A. Camus
Australia

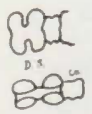


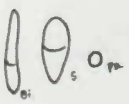
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 20.



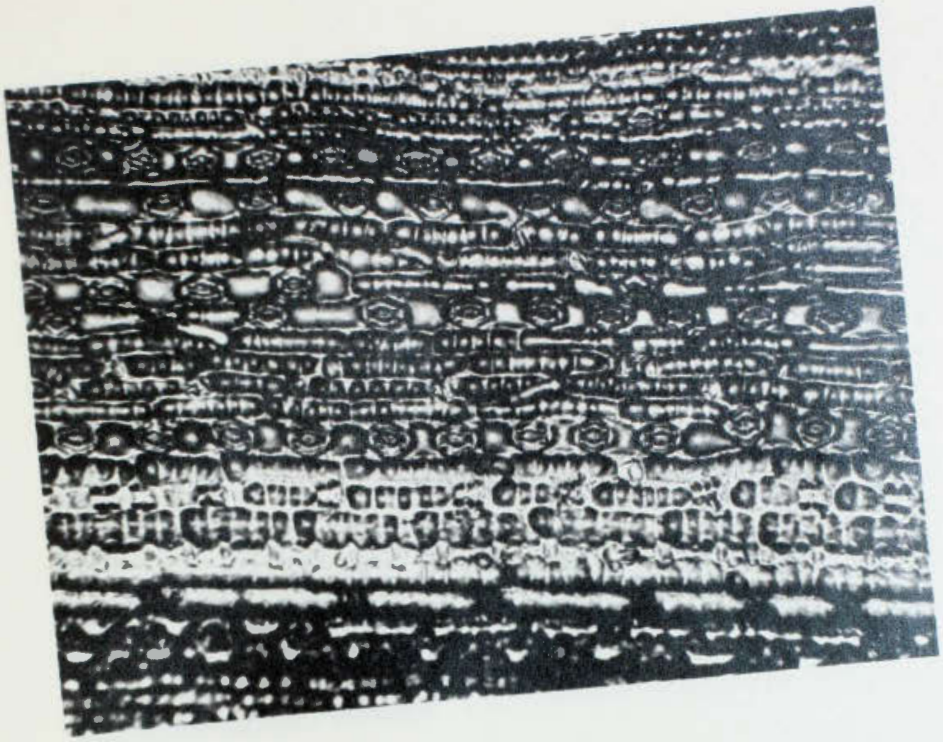
Bothriochloa intermedia A. Camus
Australia



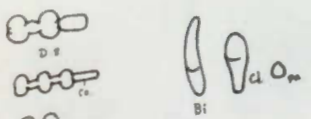


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 21.

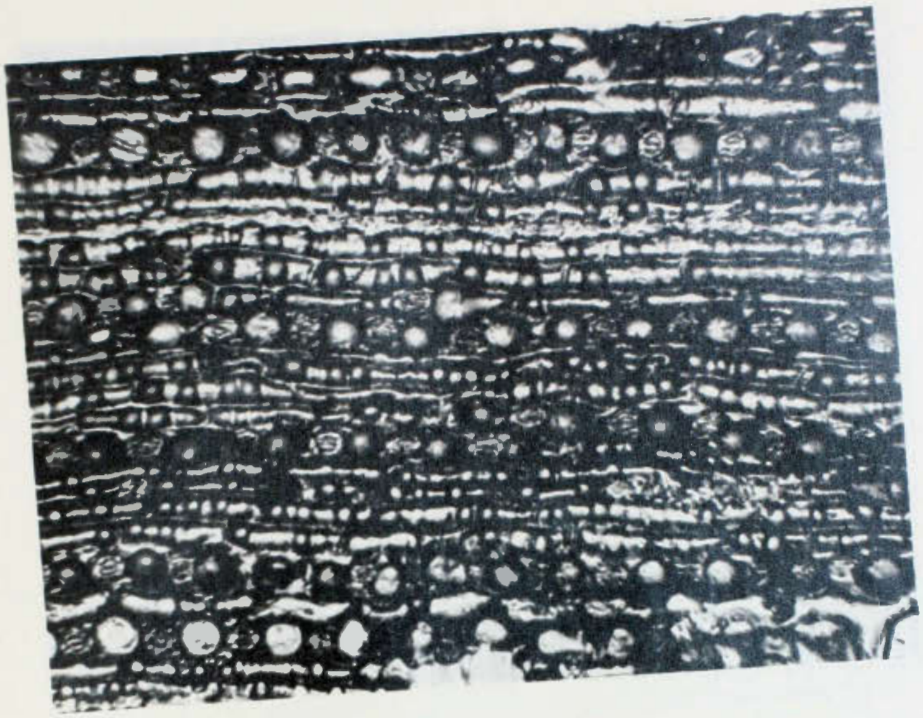


Bothriochloa intermedia A. Camus
Delhi, India (Hexaploid)

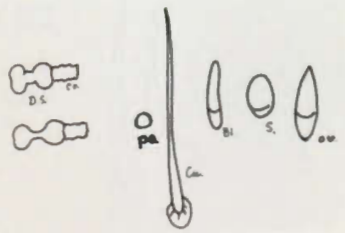


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 22.

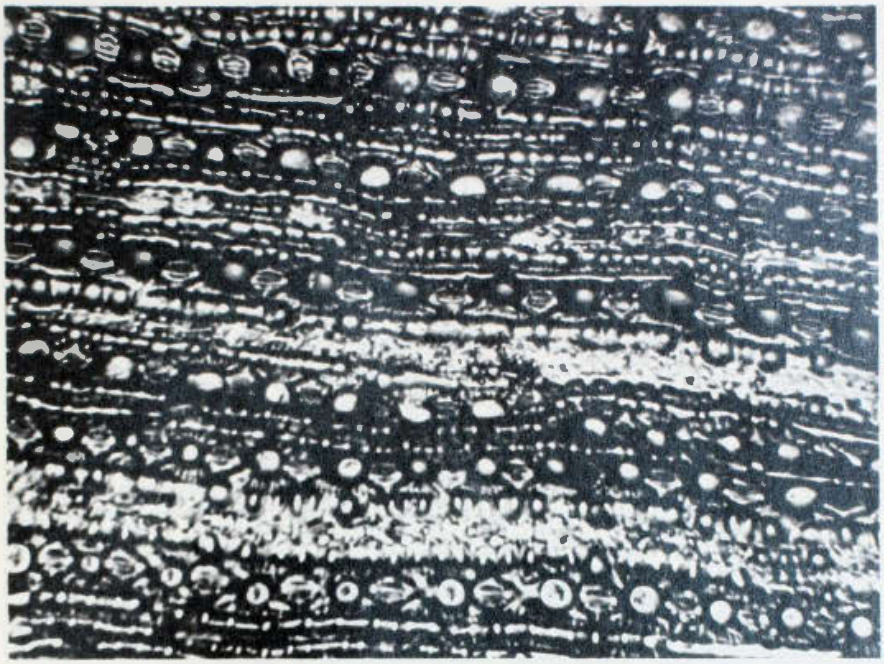


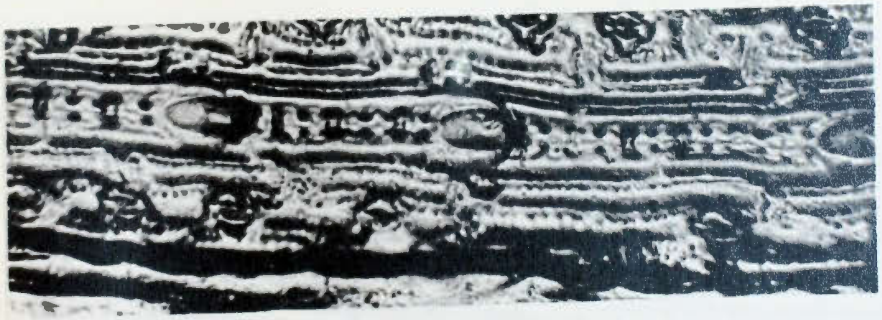
Bothriochloa ischaemum Keng
Amoy, China, via Woodward, Oklahoma



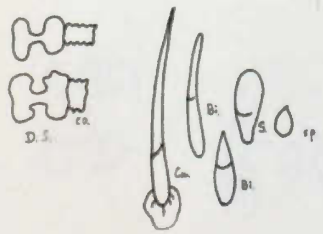
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 23.



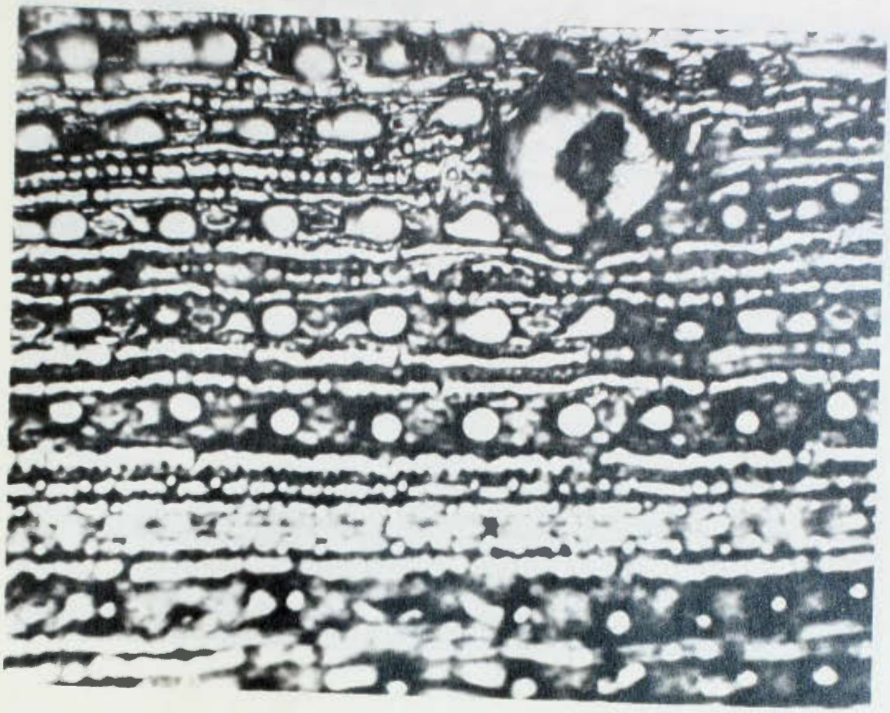


Bothriochloa ischaemum Keng
Formosa

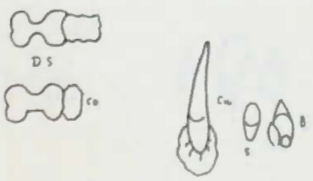


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 24.

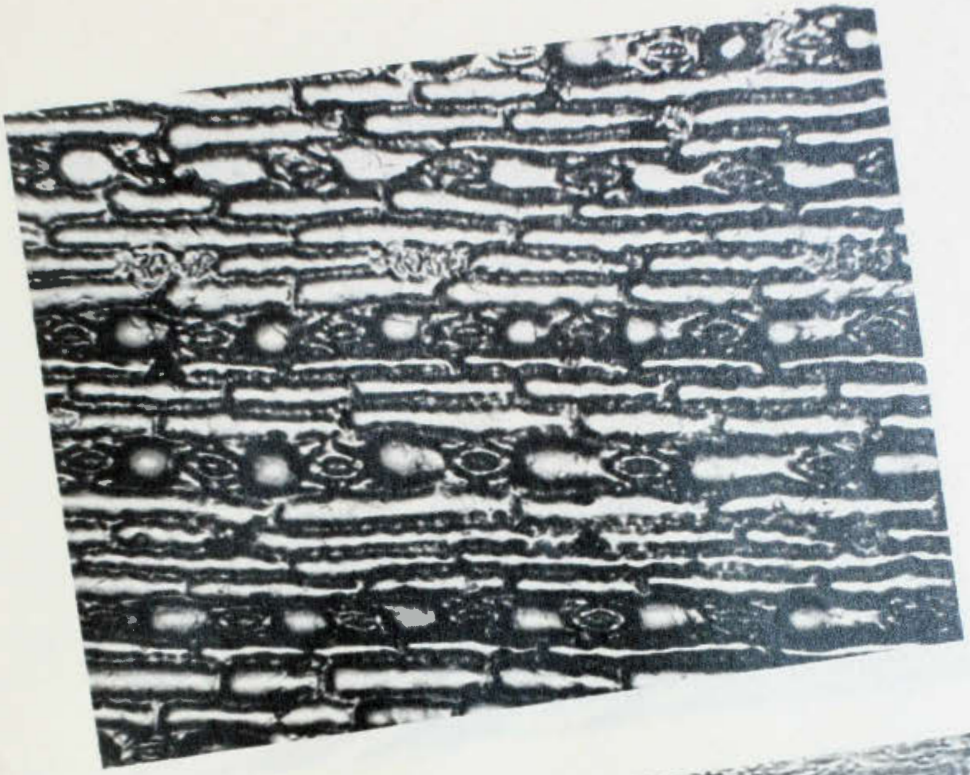


Bothriochloa ischaemum Keng
Austria

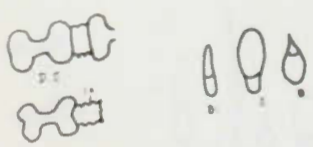


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 25.

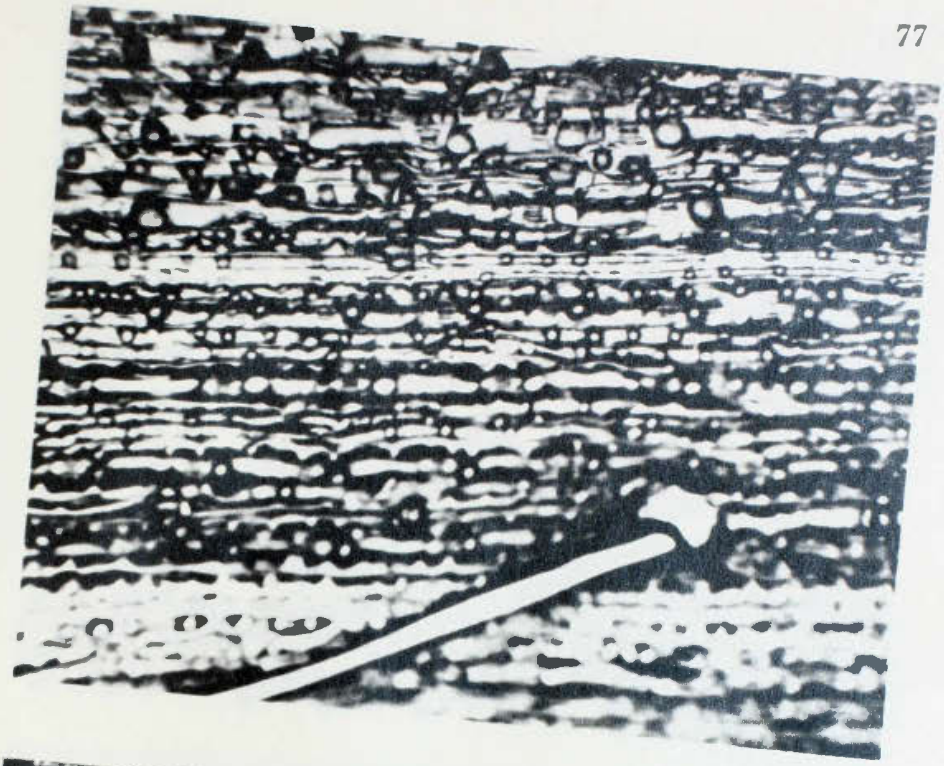


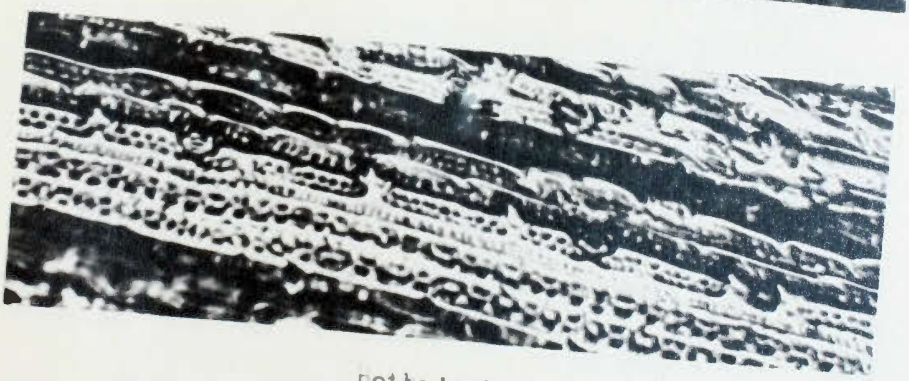
Bothriochloa erianthoides C. E. Hubbard



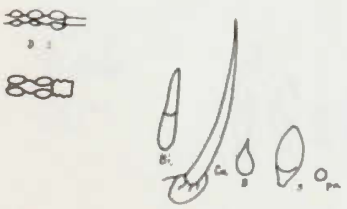
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 26.



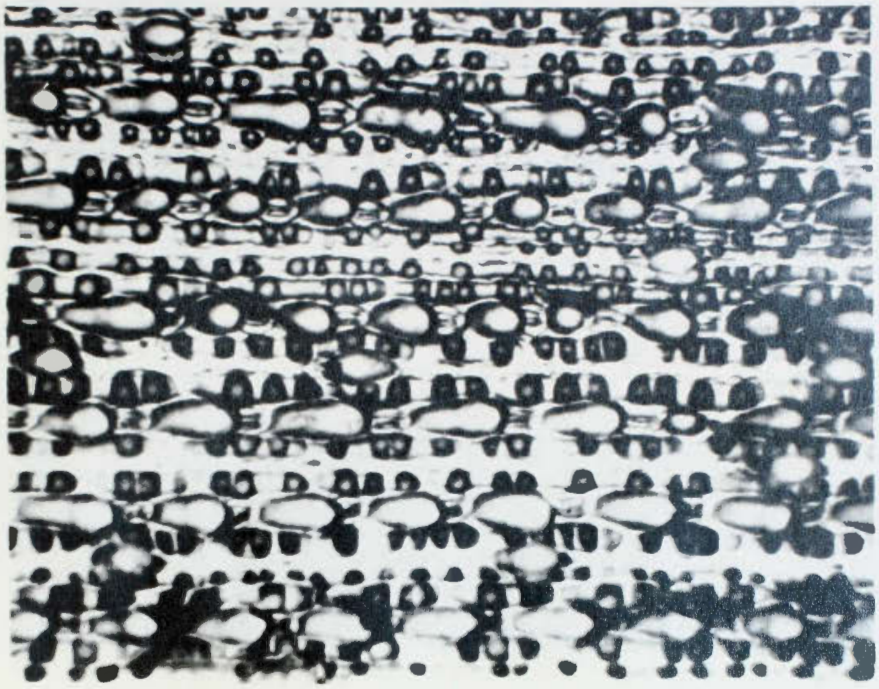


Bothriochloa pertusa A. Camus



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

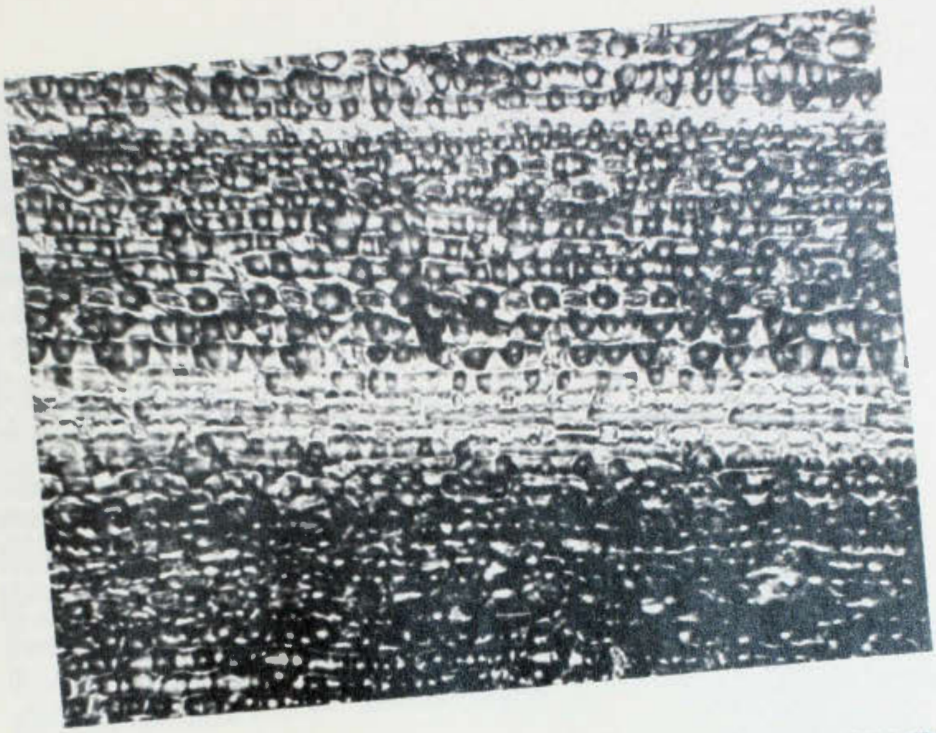
Fig.-27.



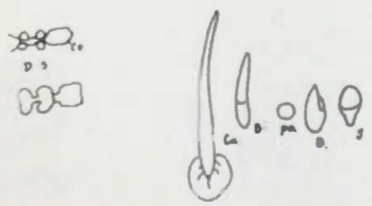
Bothriochloa radicans A. Camus
Kenya, Africa

Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 20.



Bothriochloa radicans?
Nairobi, Kenya, Africa



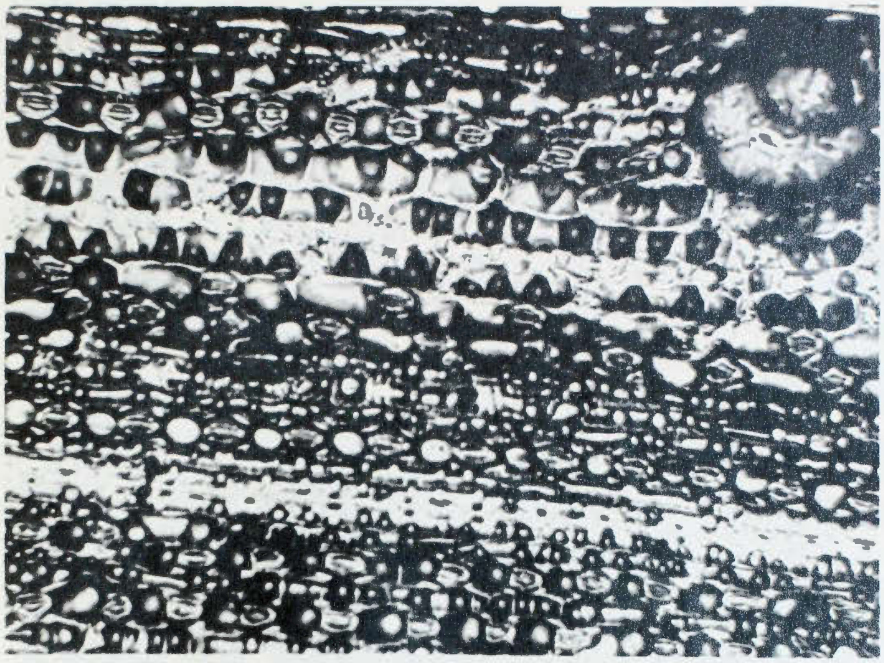
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 29.

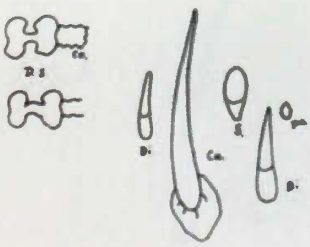
Bothriochloa saccharoides Pydb.

Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 30.

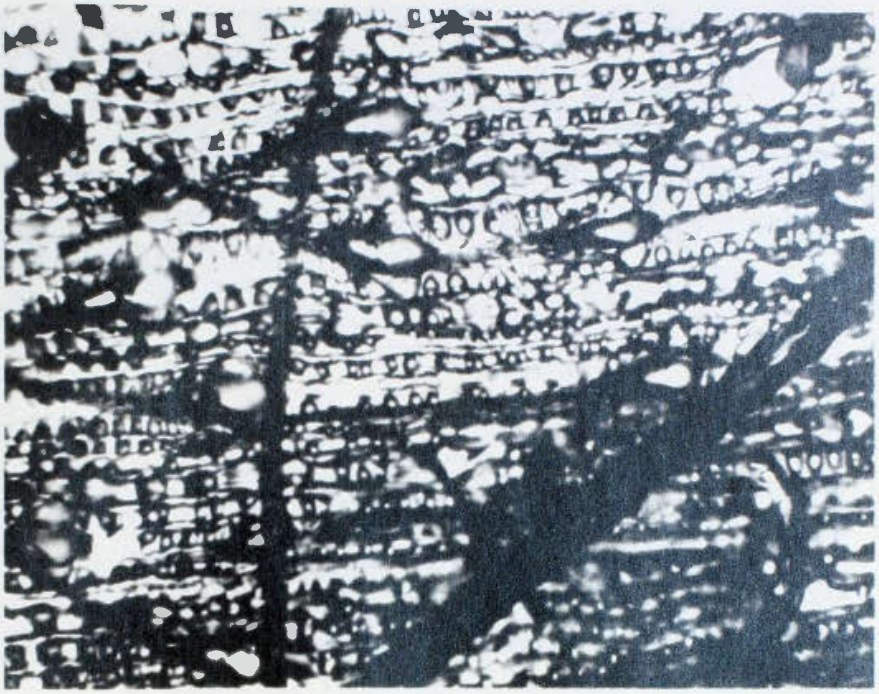


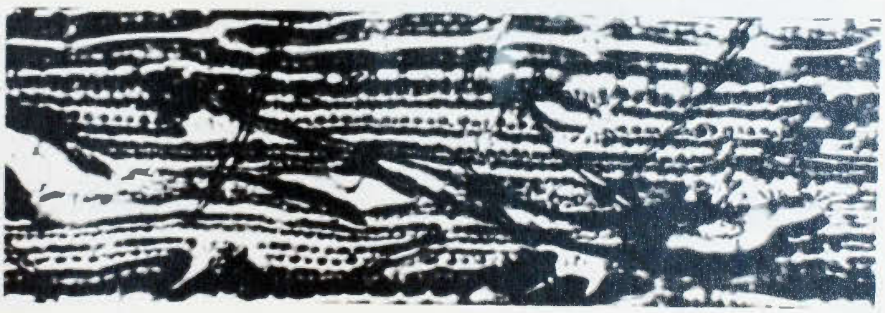
Bothriochloa venusta A. Camus



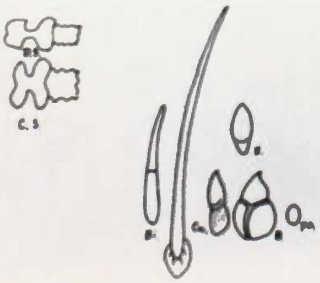
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 31.



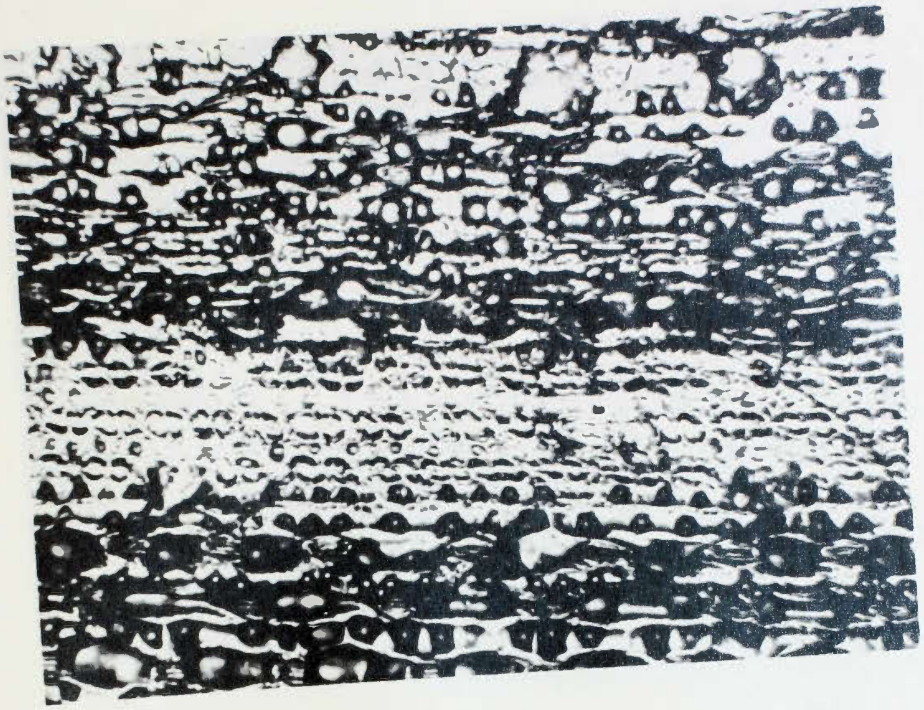


Capillipedium parviflorum Stapf

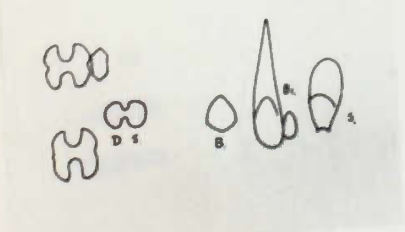


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 32.

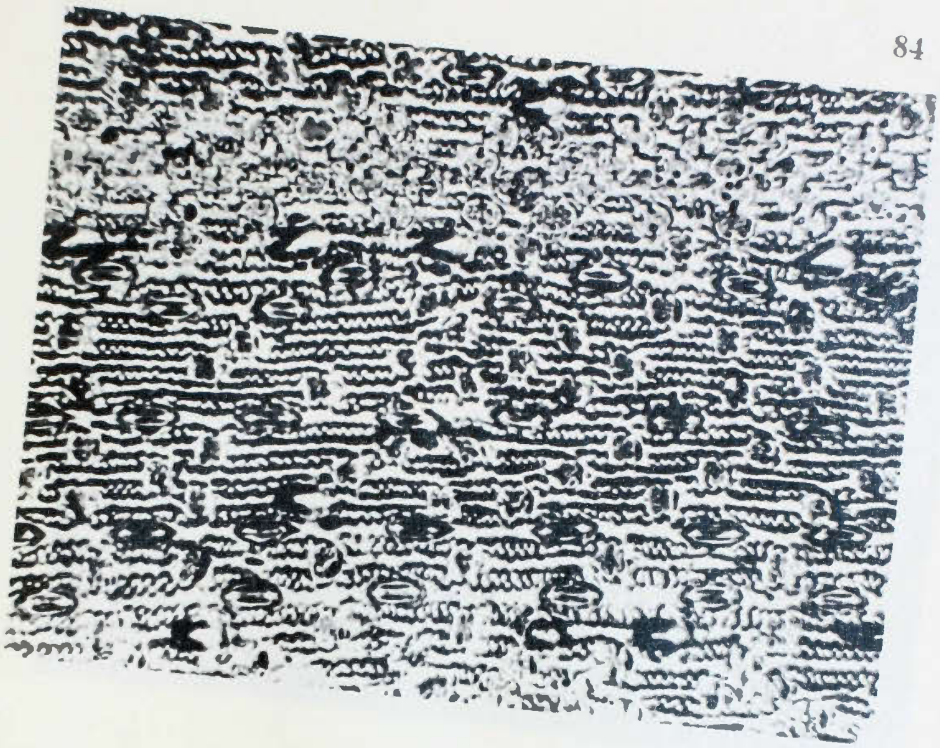


Capillipedium spicigera

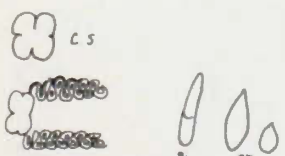


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 33.

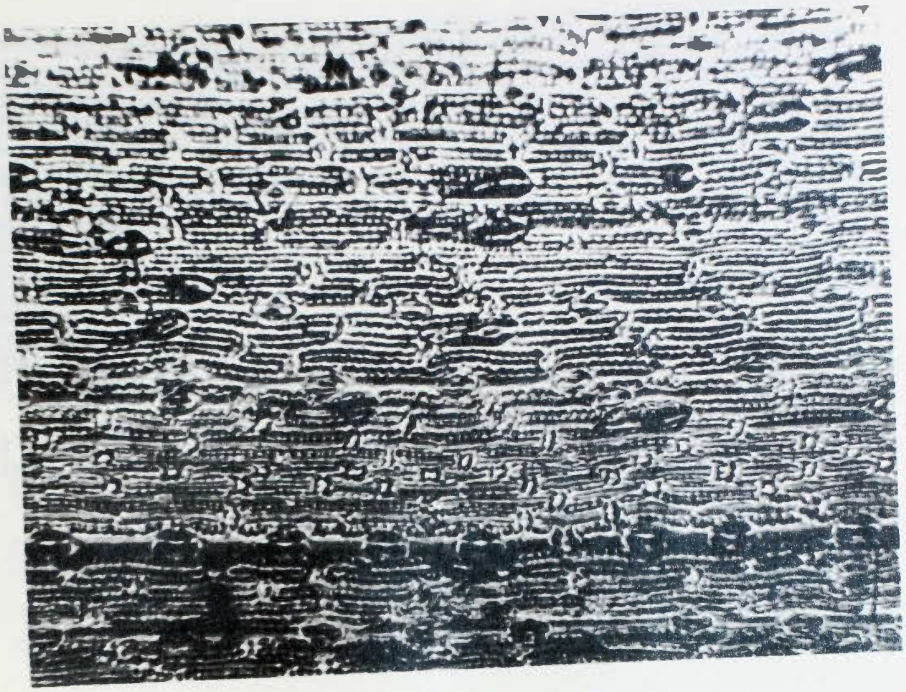


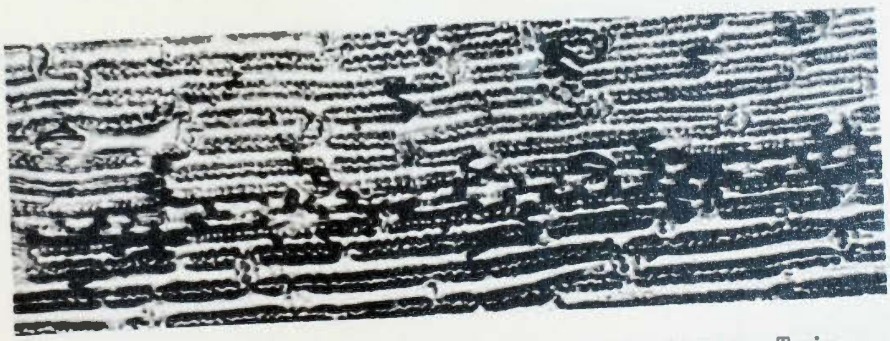
Chrysopogon aucheri Stapf



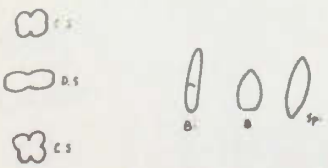
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 24.



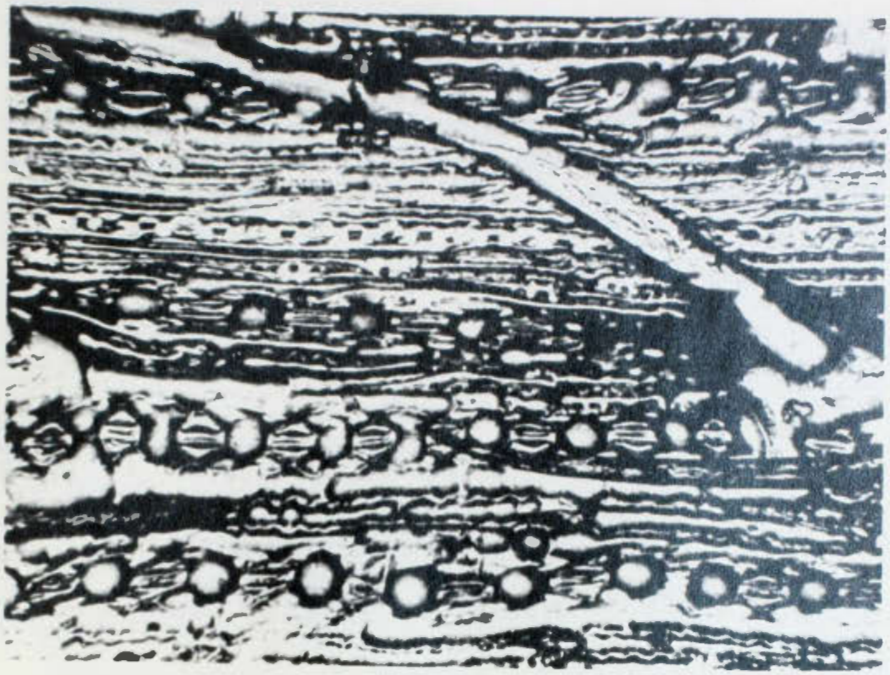


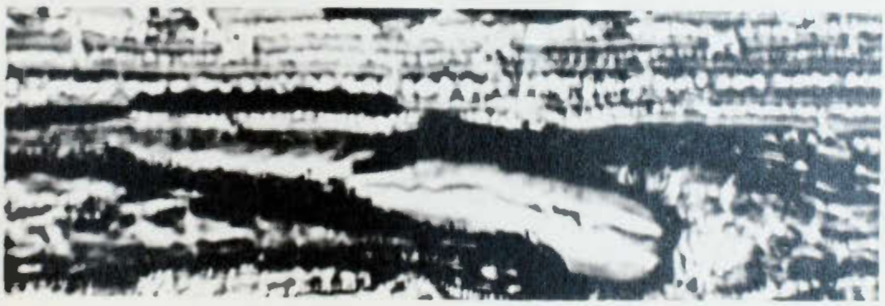
Chrysopogon montanus Trin.



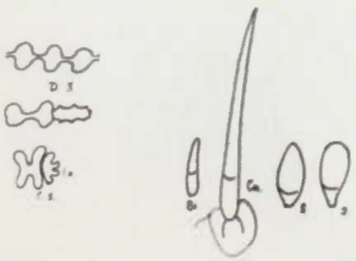
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 35.



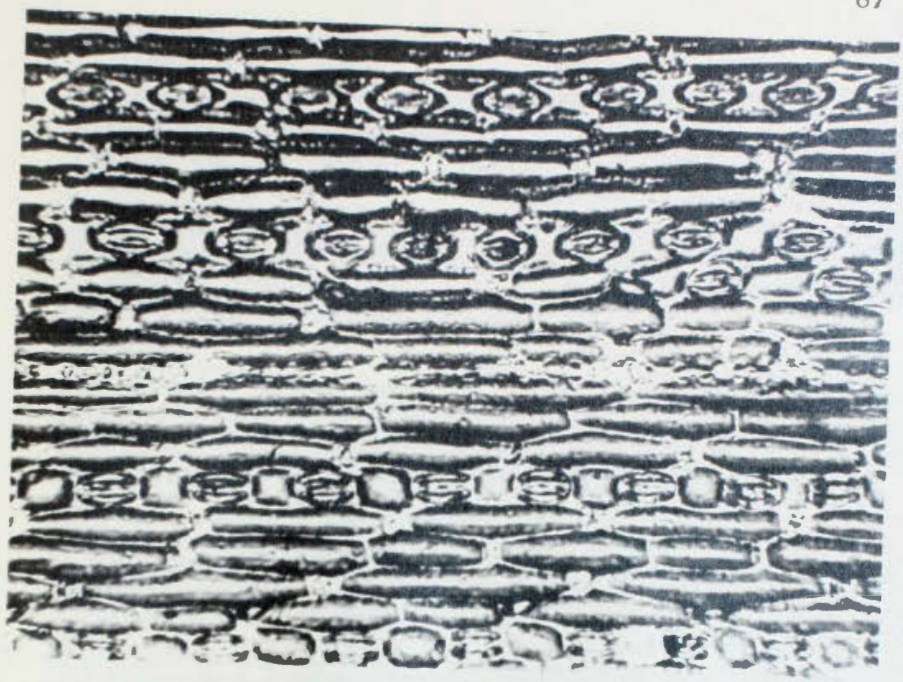


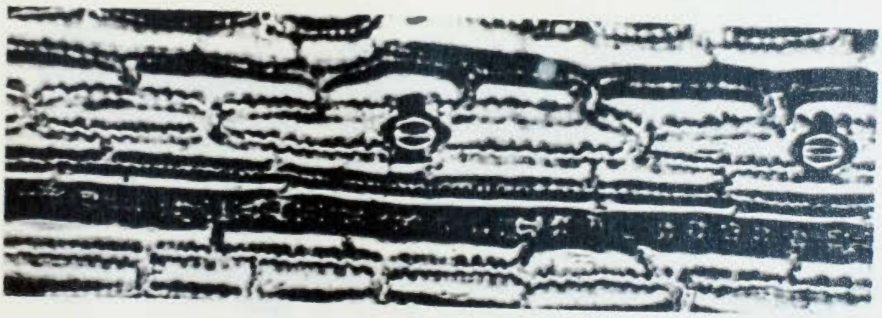
Cleistachne sorghoides Benth.



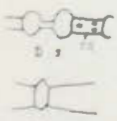
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 76.



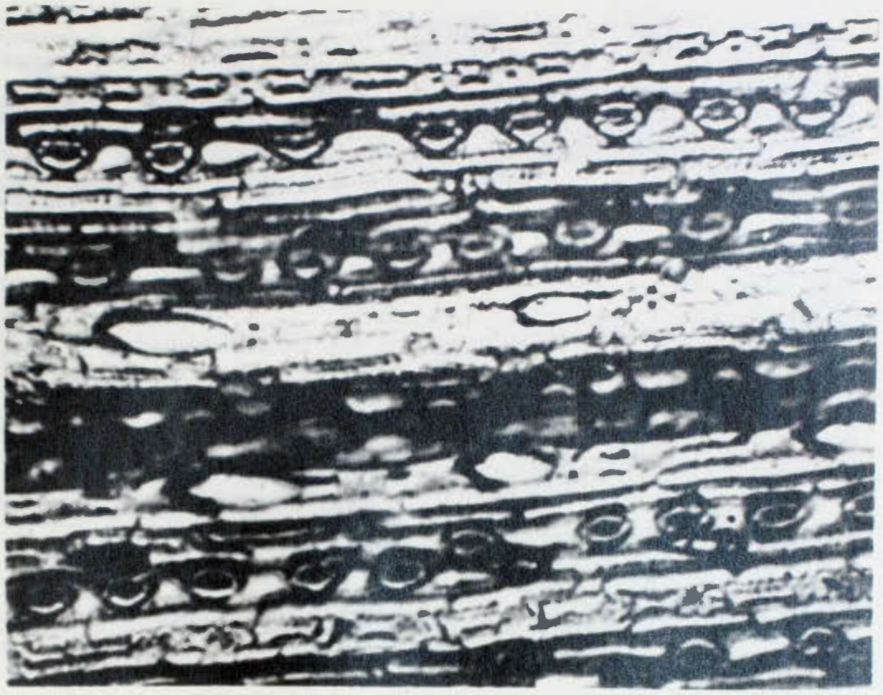


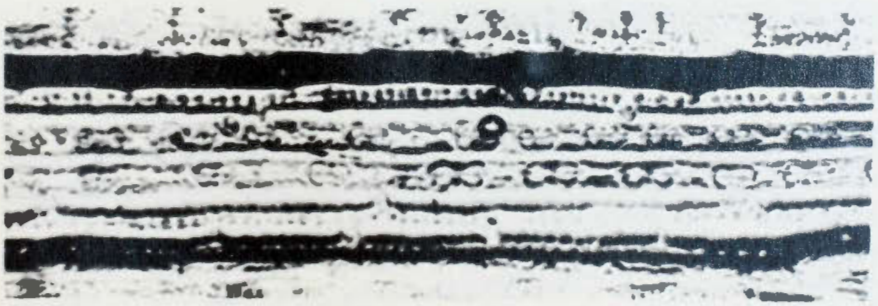
Cymbopogon bombycinus Domin.



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 37.

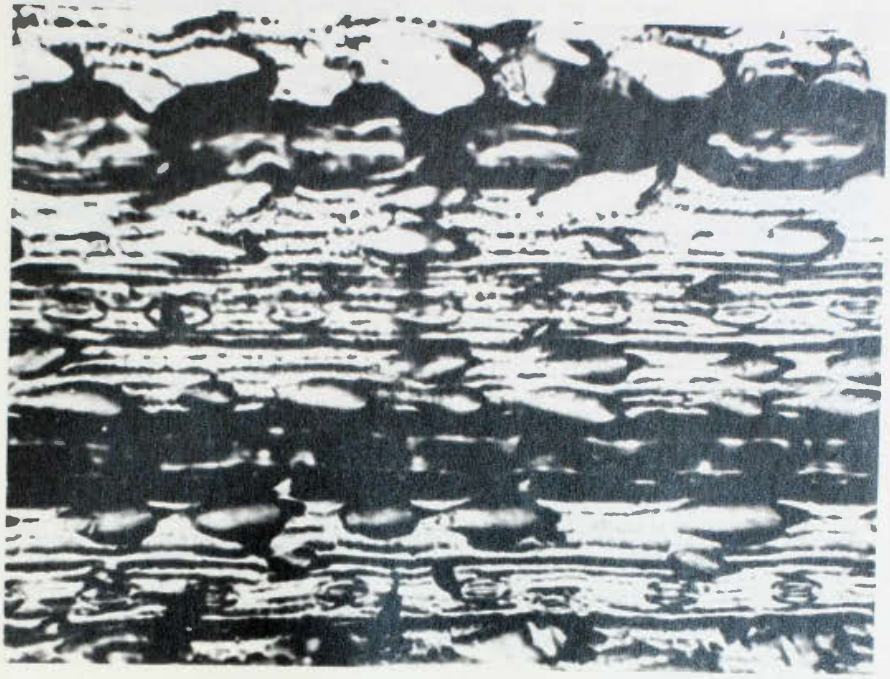


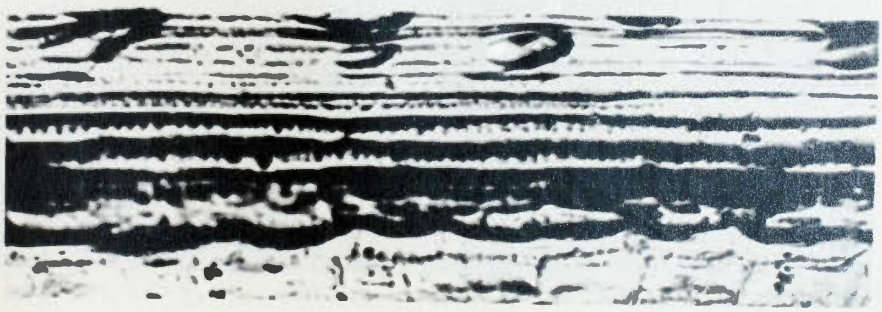


Cymbopogon excavatus

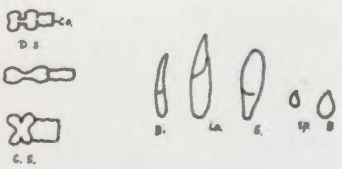
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 38.



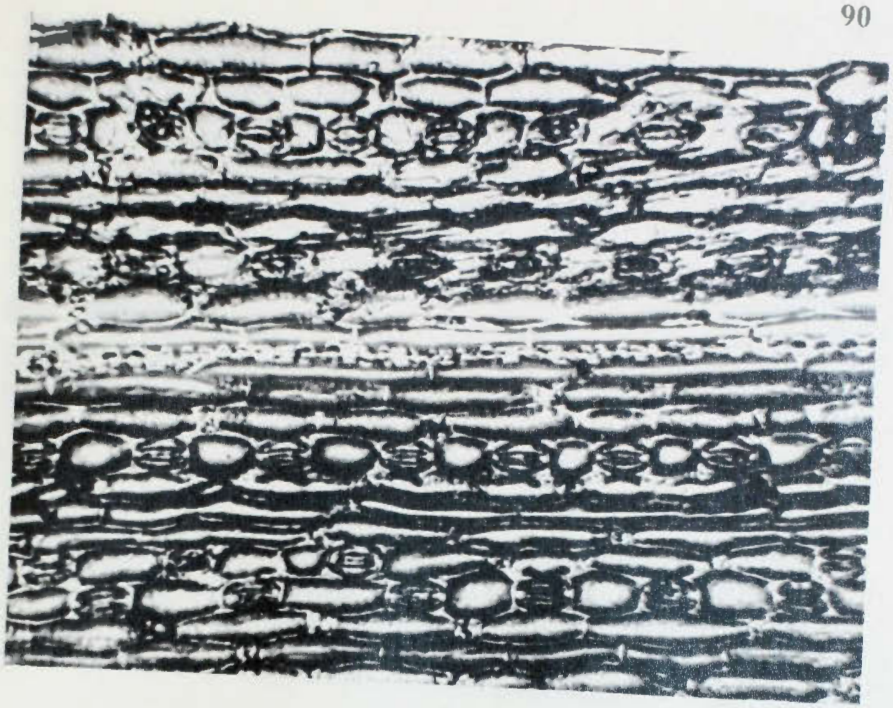


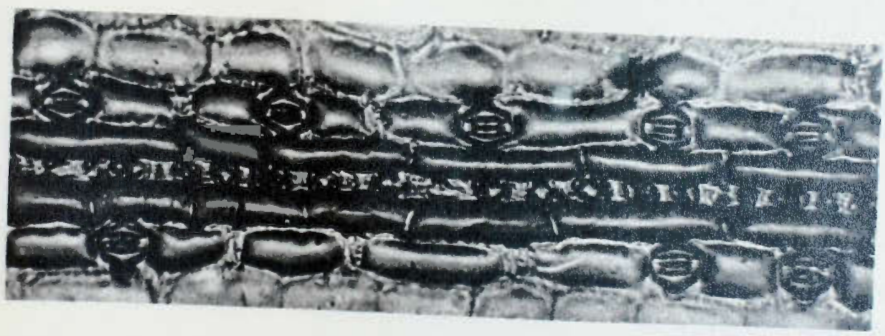
Cymbopogon hookeri



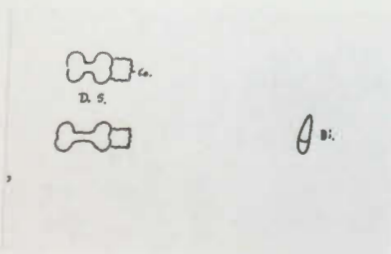
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 39.



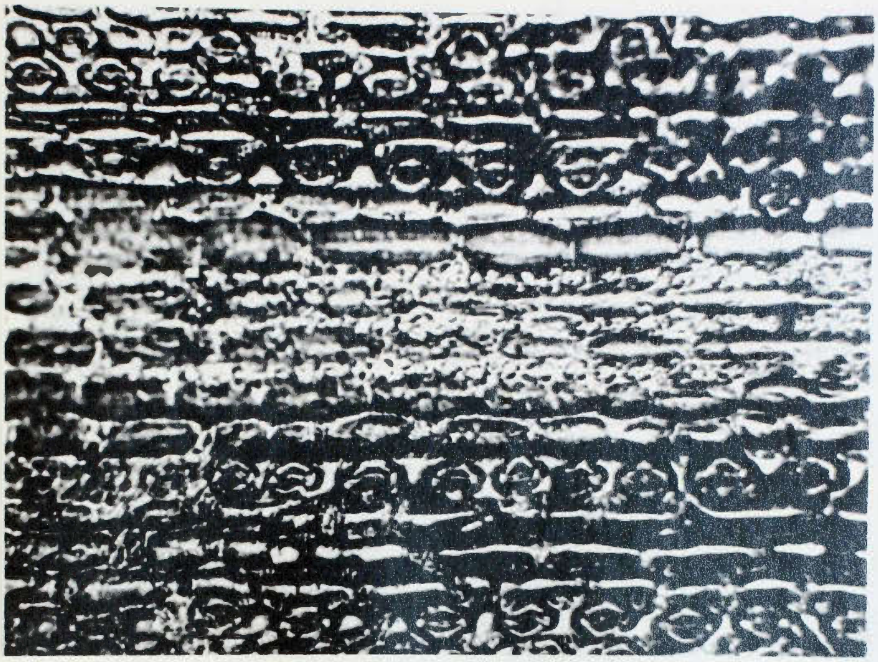


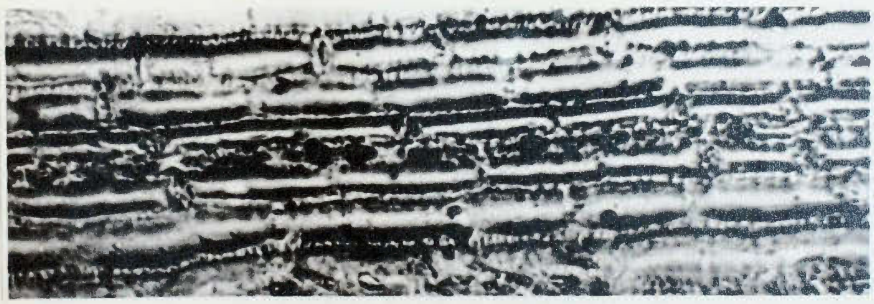
Cymbopogon martinii



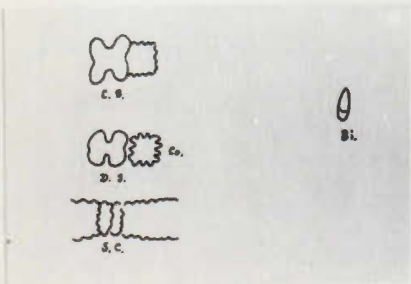
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 40.



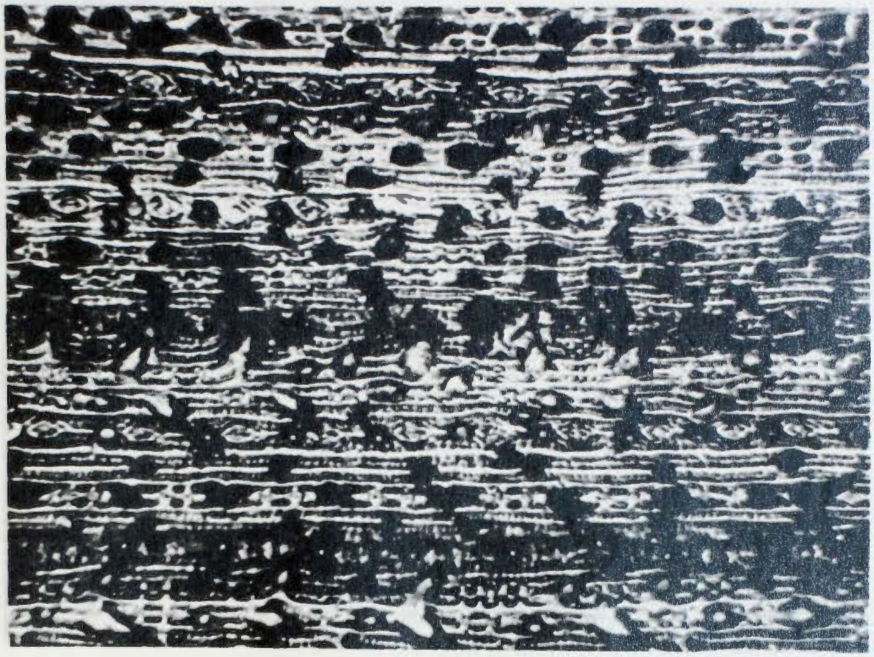


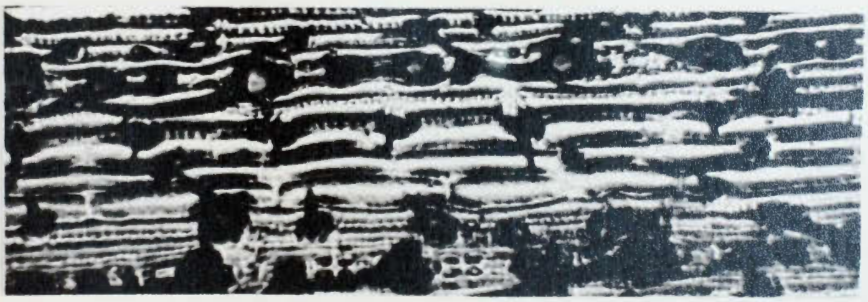
Cymbopogon sp.



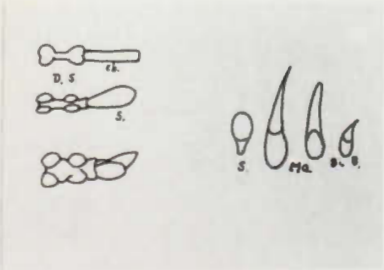
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 41.



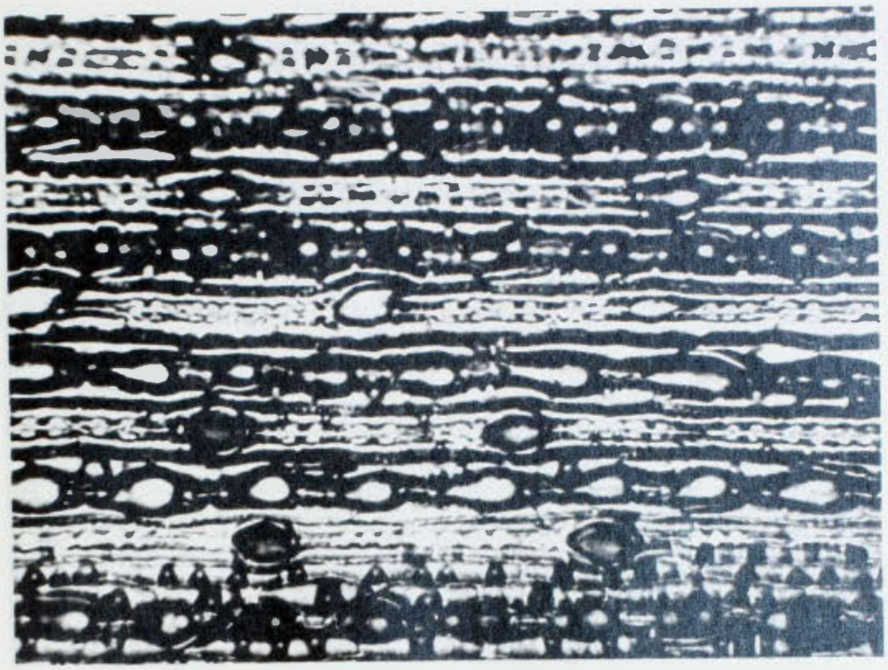


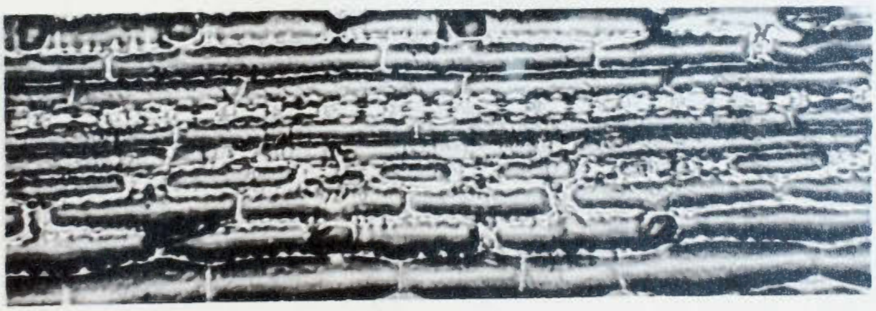
Diectomis Kunth



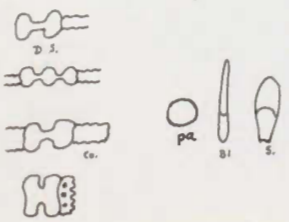
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 42.



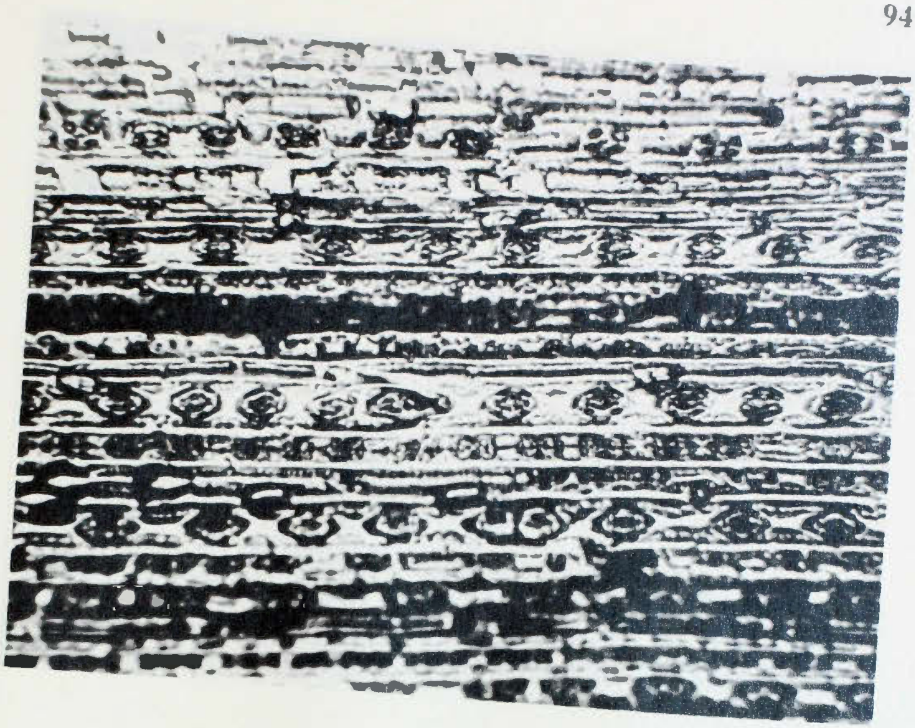


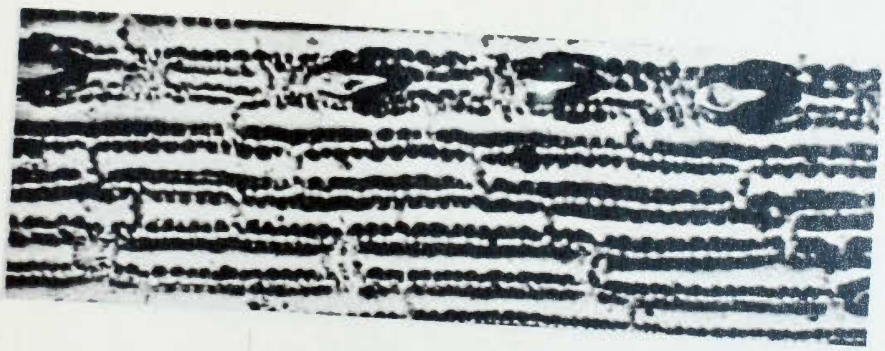
Dichanthium annulatum Stapf



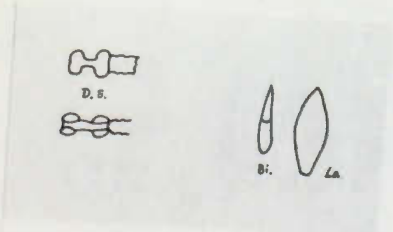
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 43.



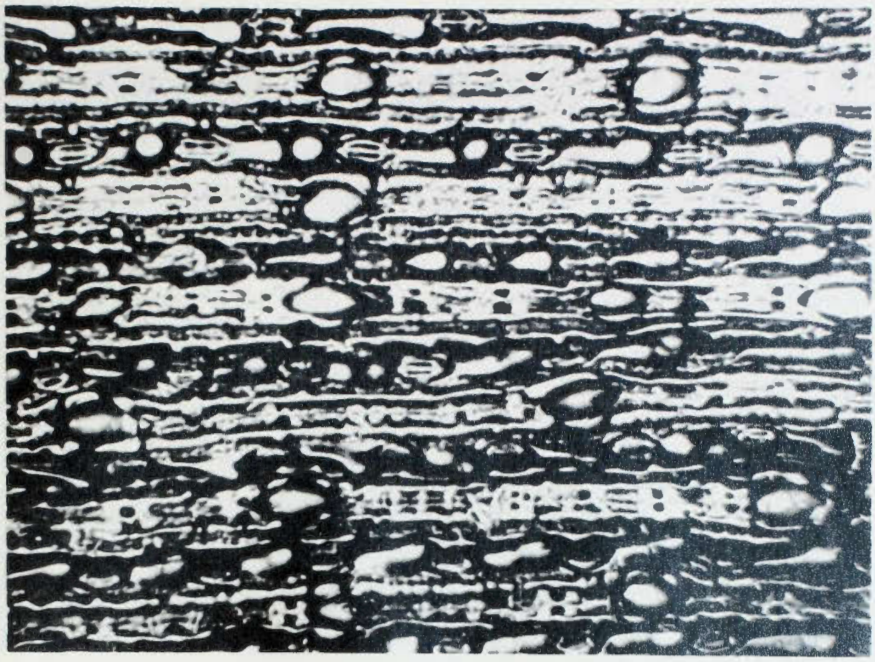


Dichanthium aristatum C. E. Hubbard

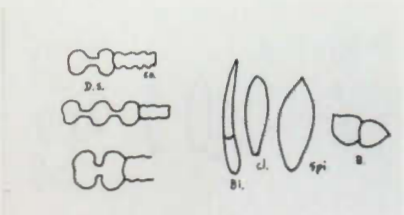


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 44.

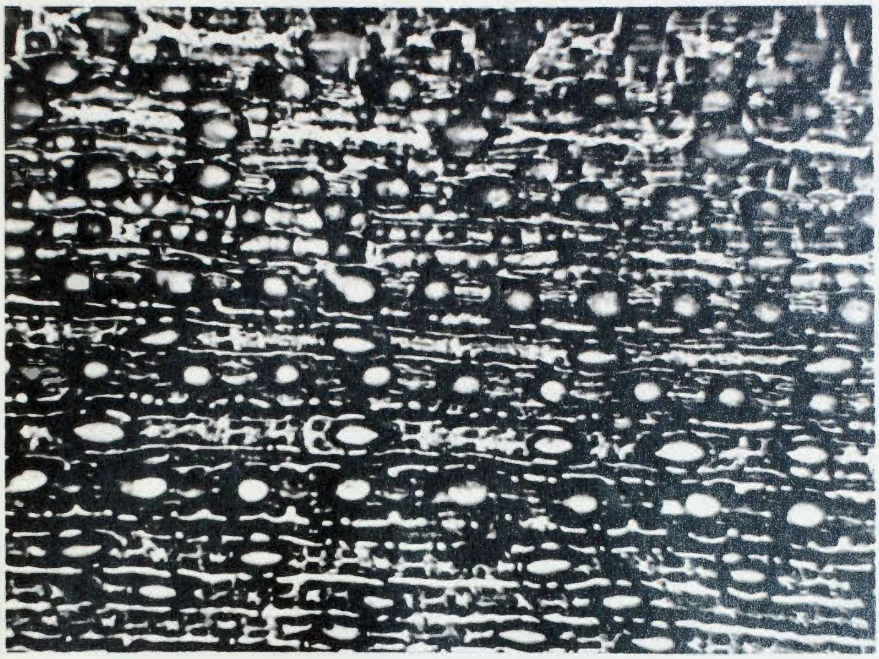


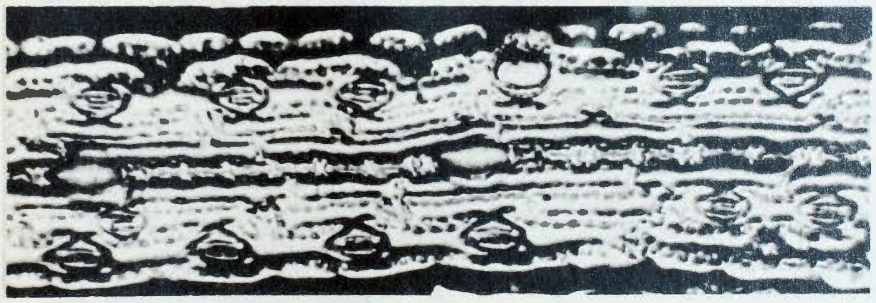
Dichanthium caricosum A. Camus



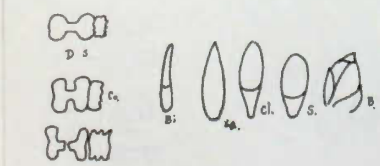
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 45.



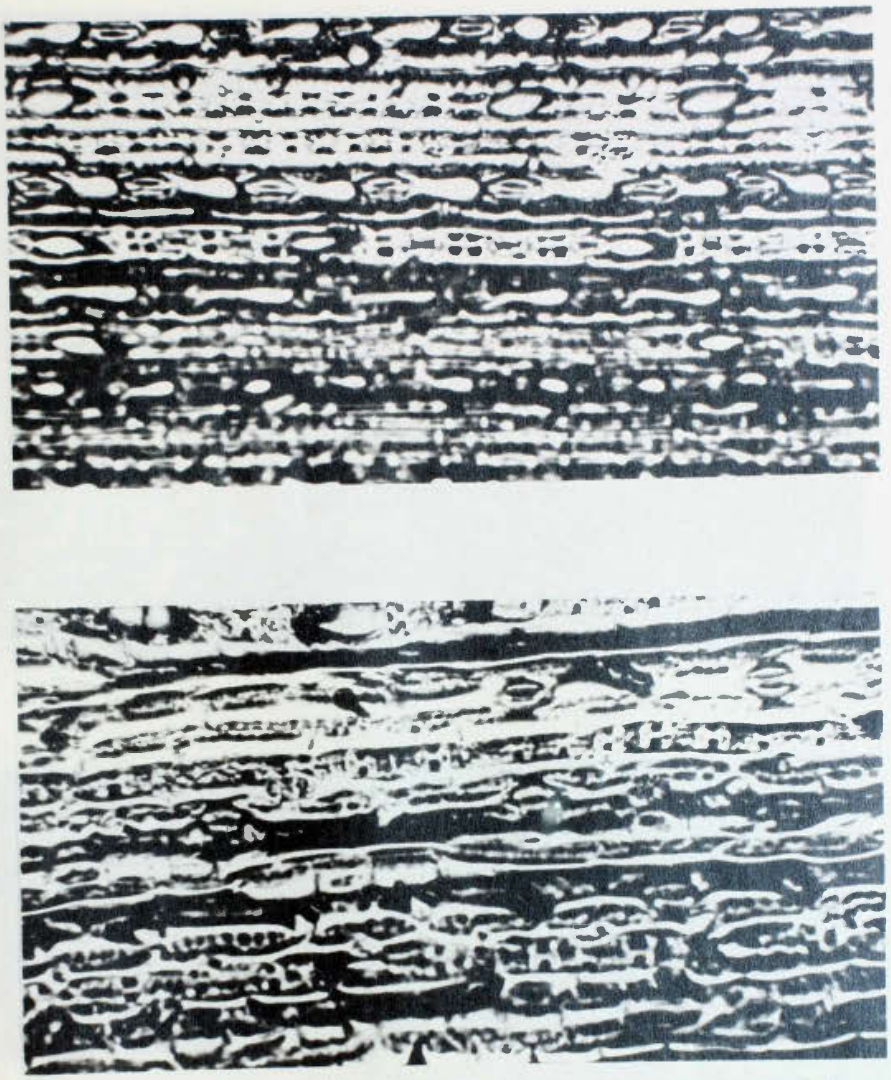


Dichanthium caricosum
Malay (Deep purple stem)

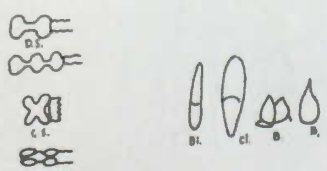


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 46.



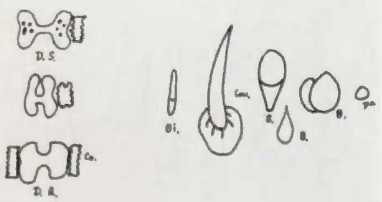
Dichanthium caricosum var. media
(not flowering)



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

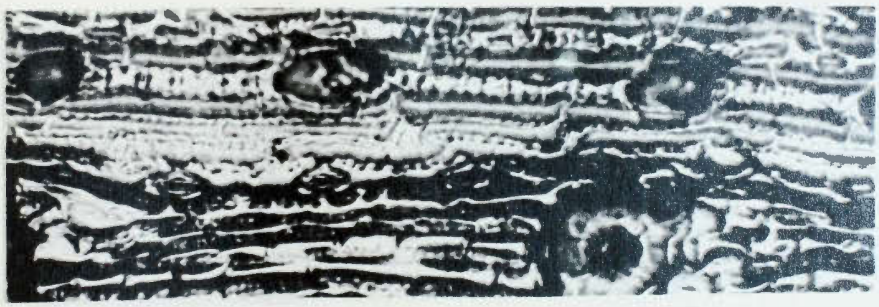
Fig. 47.

Dichanthium papillosum Stapf

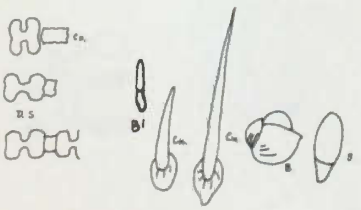


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 48.

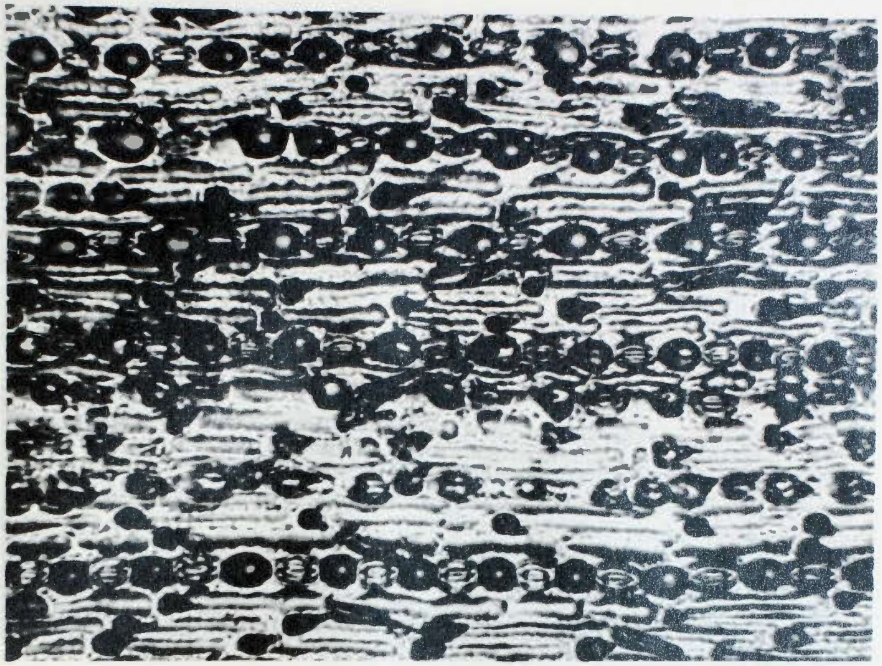


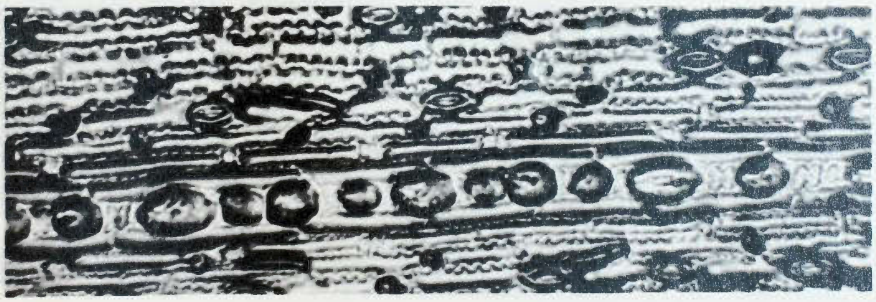
Dichanthium sericeum A. Camus



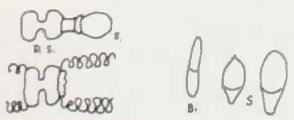
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 19.



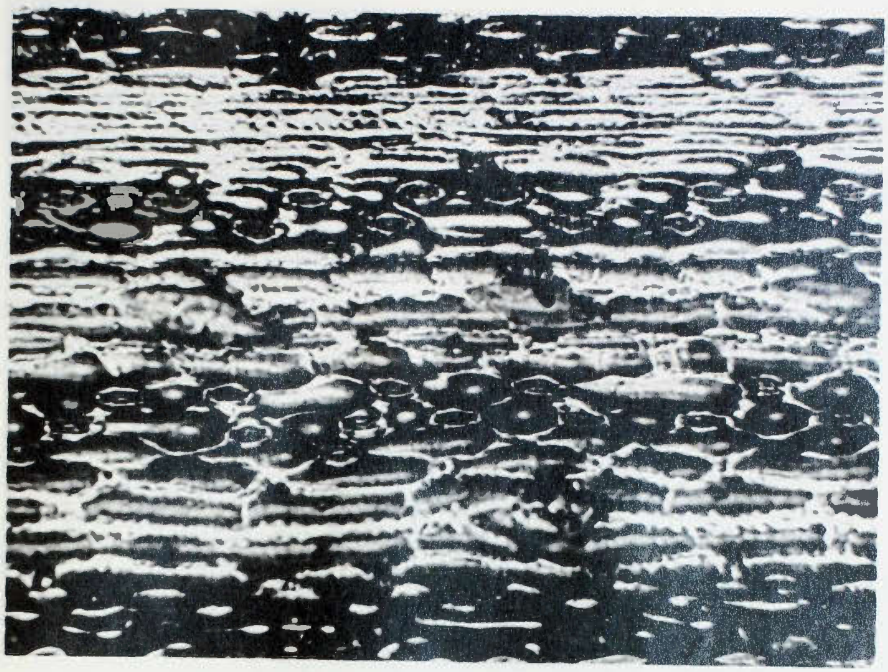


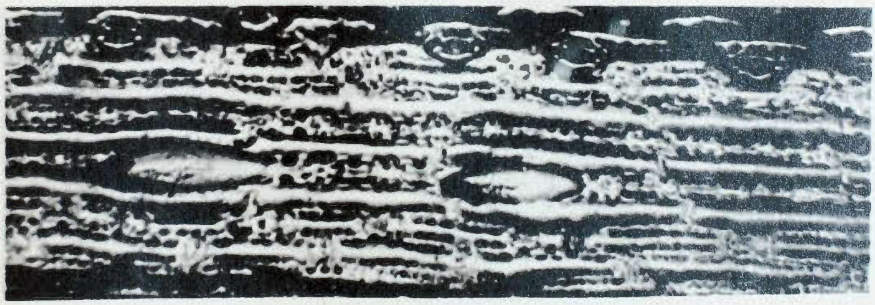
Erianthus longisetosus



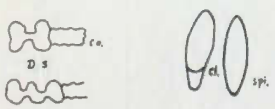
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 50.



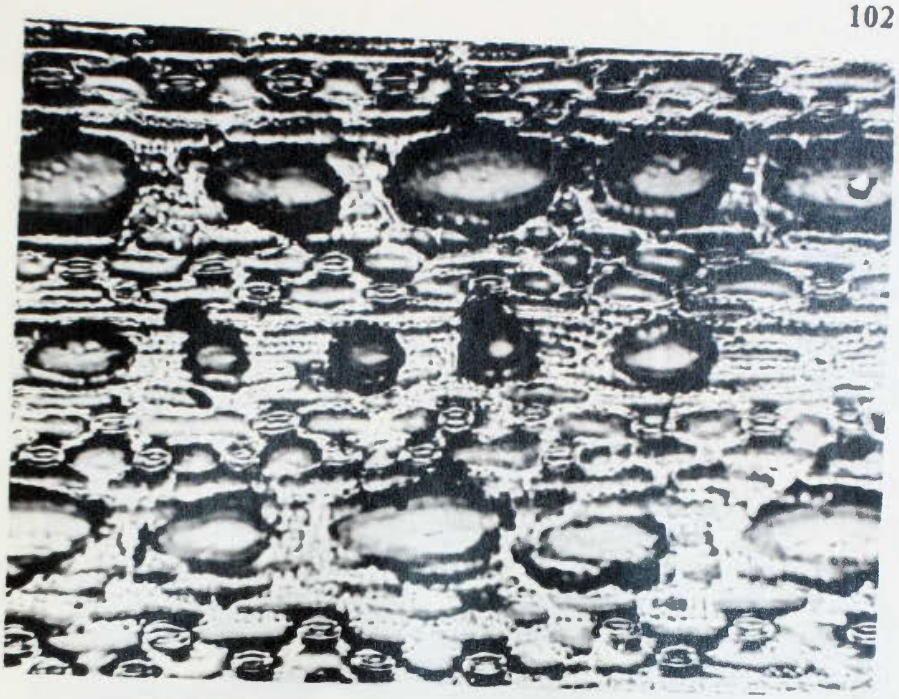


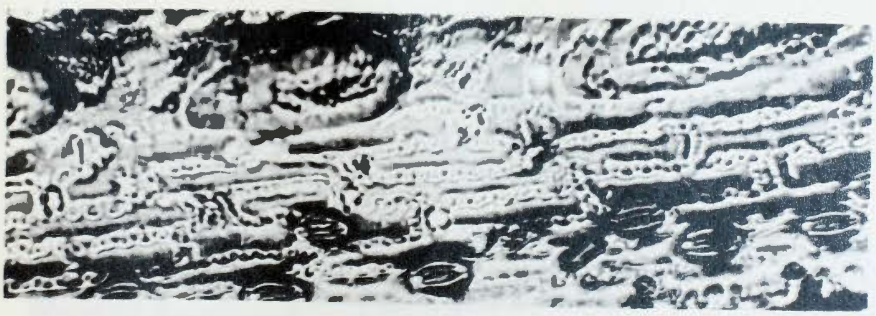
Erianthus ravennae (L.) Beauv.



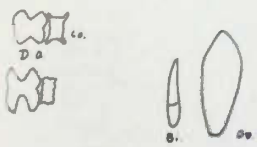
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 51.



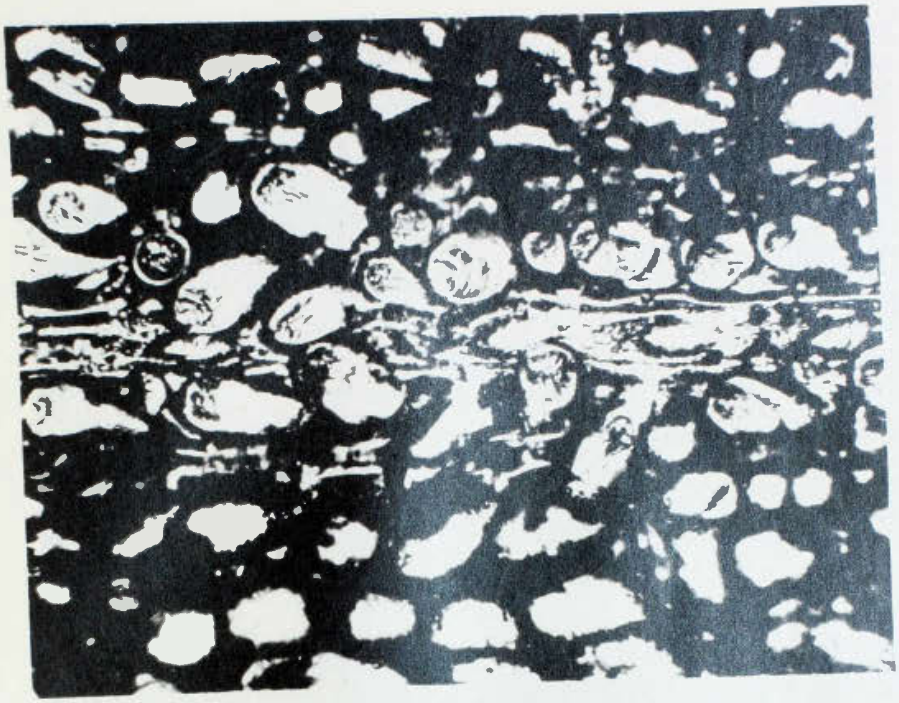


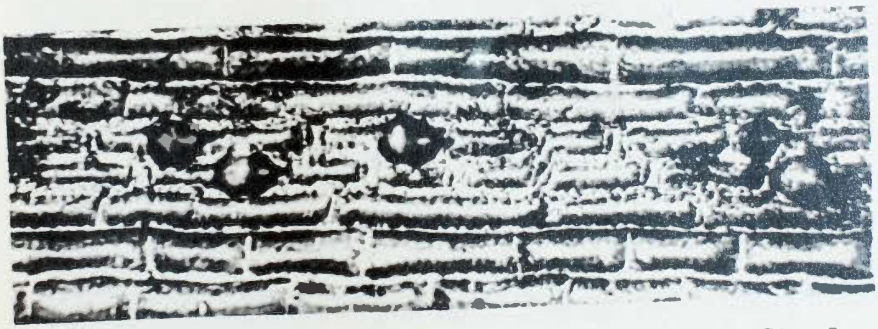
Erianthus sp.



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 52.

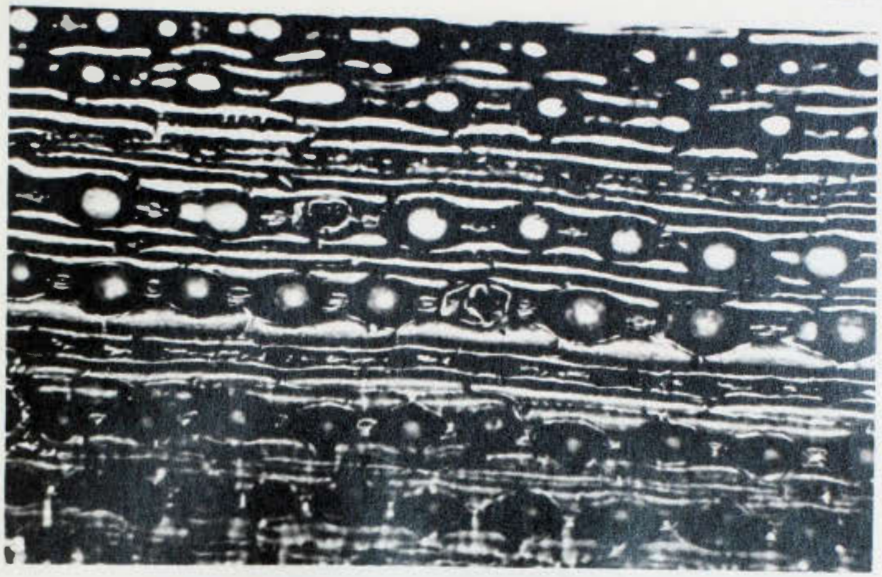


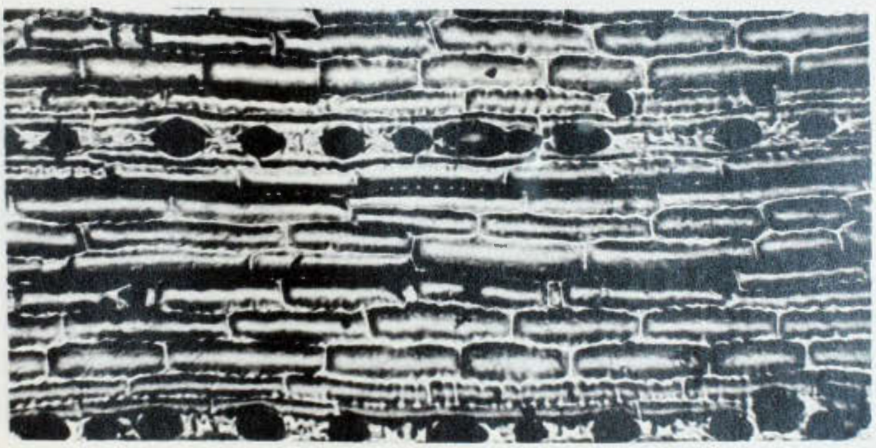


Eremopogon faveolatus Stapf

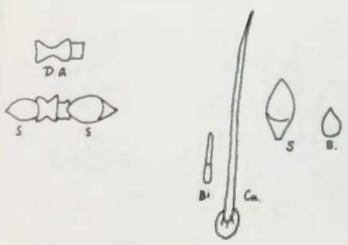
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 53.



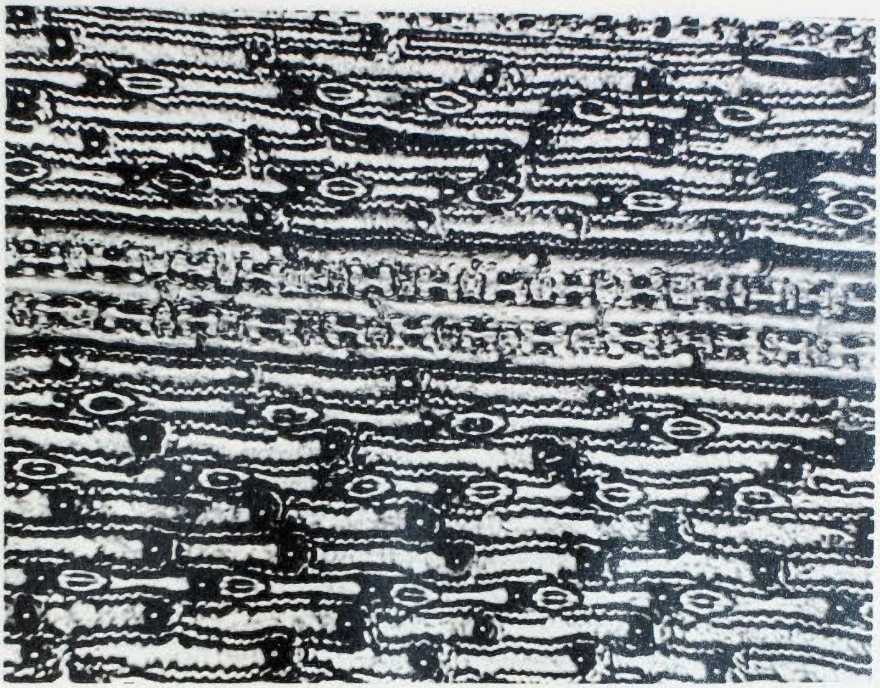


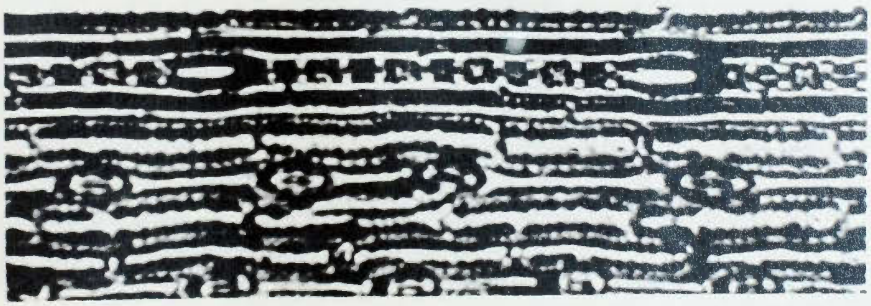
Euclasta condylotricha Stapf



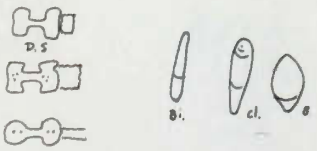
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 51.



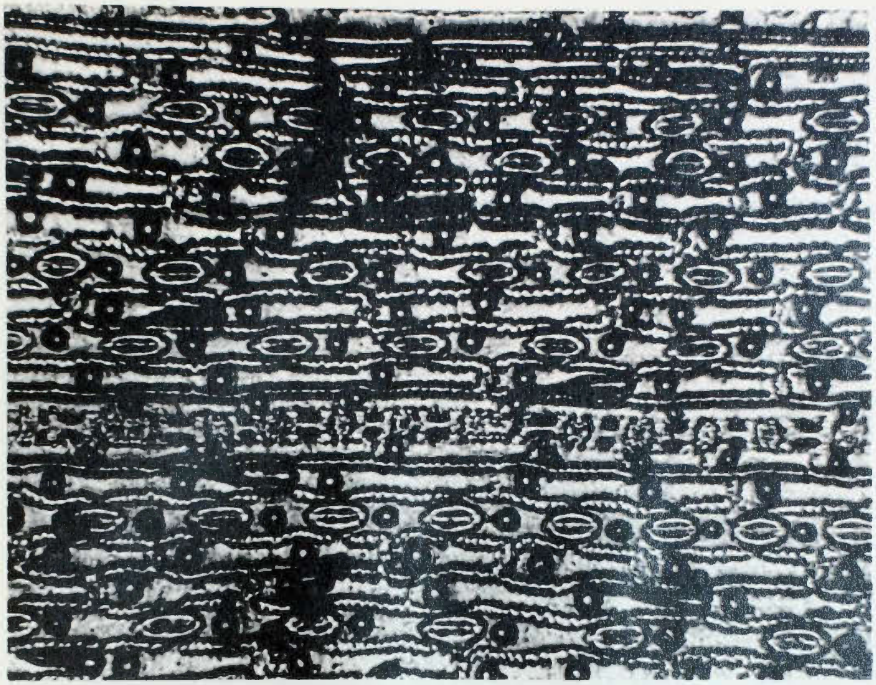


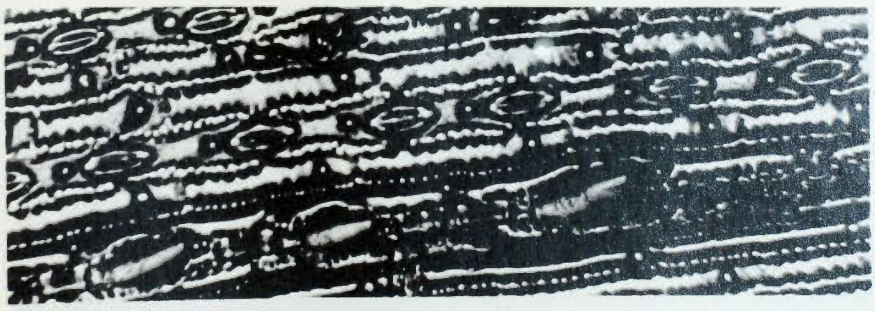
Heteropogon contortus
New Delhi, India



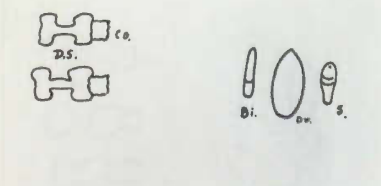
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 55.



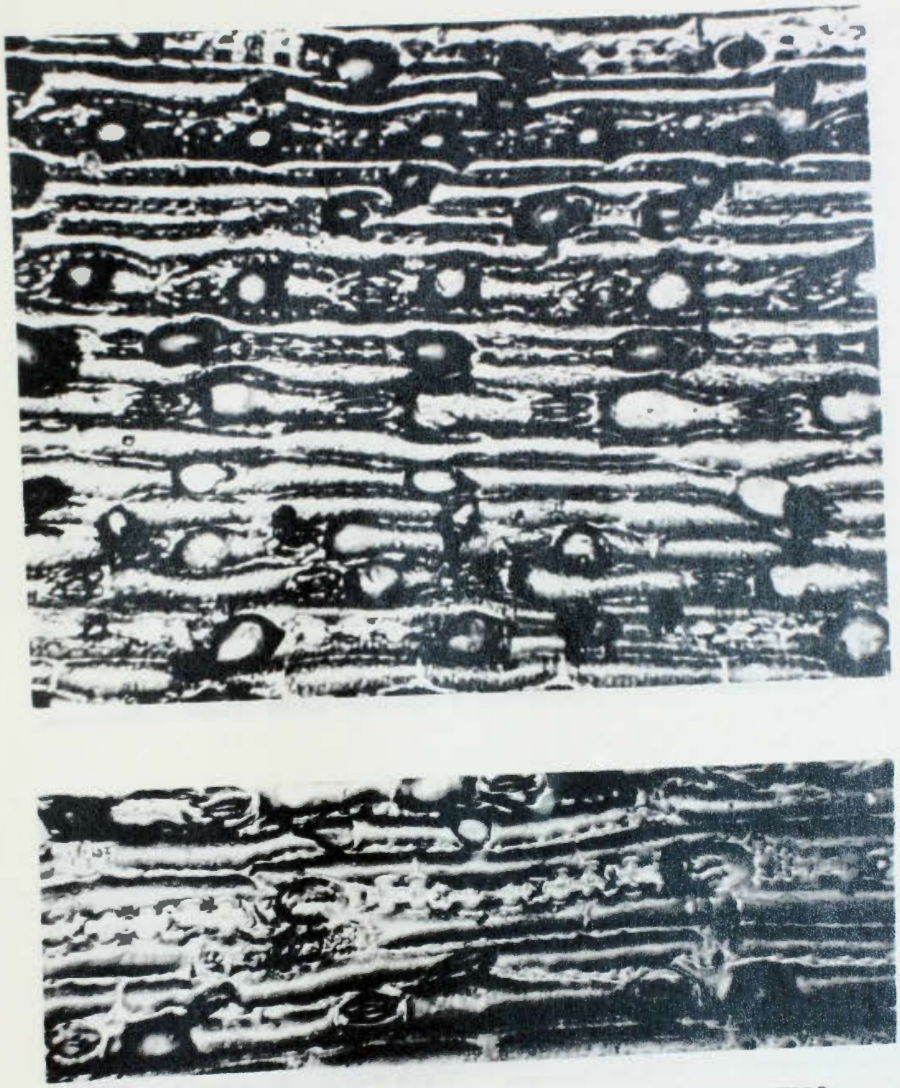


Heteropogon contortus Roem. & Schultz
Allahabad, India

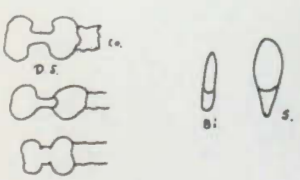


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 56.

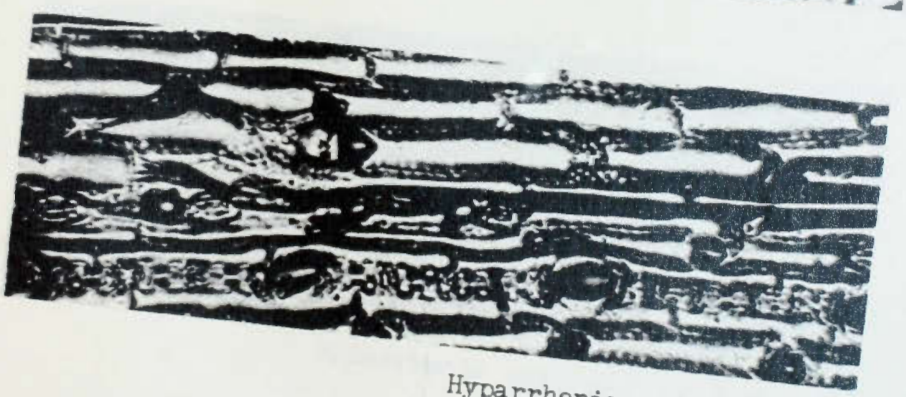


Hyparrhenia chrysargyrea

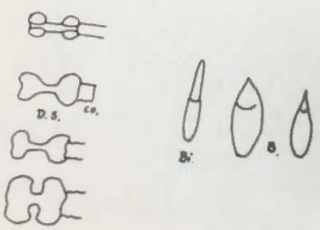


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 57.

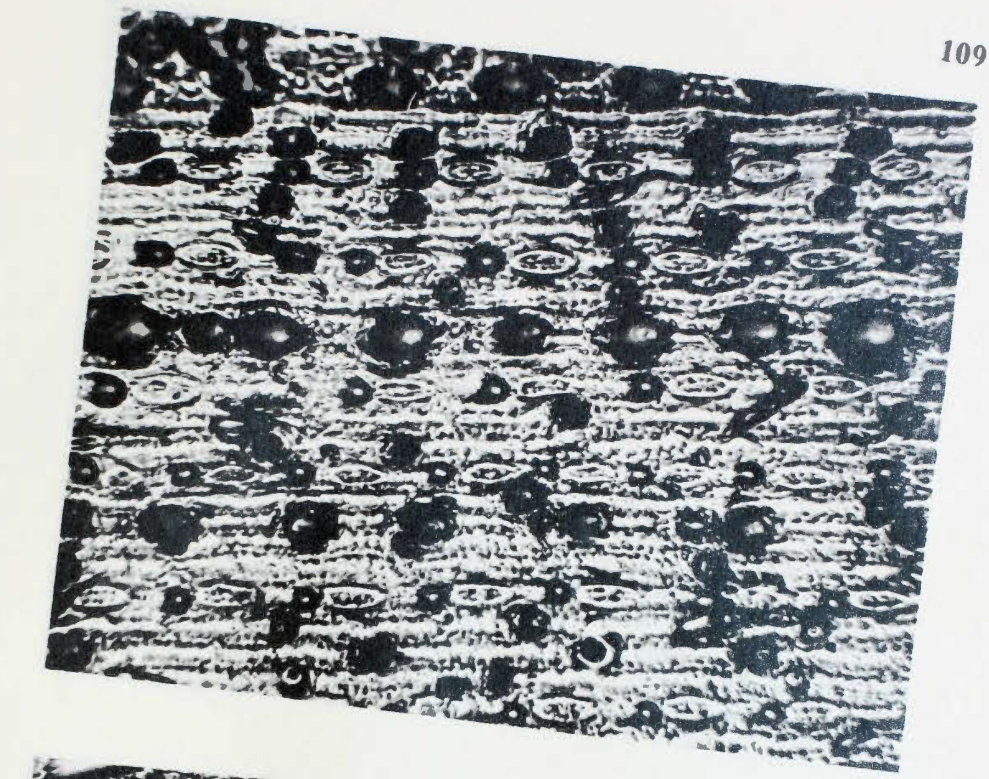


Hyparrhenia confinis

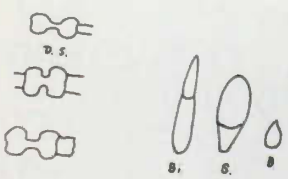


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 58.

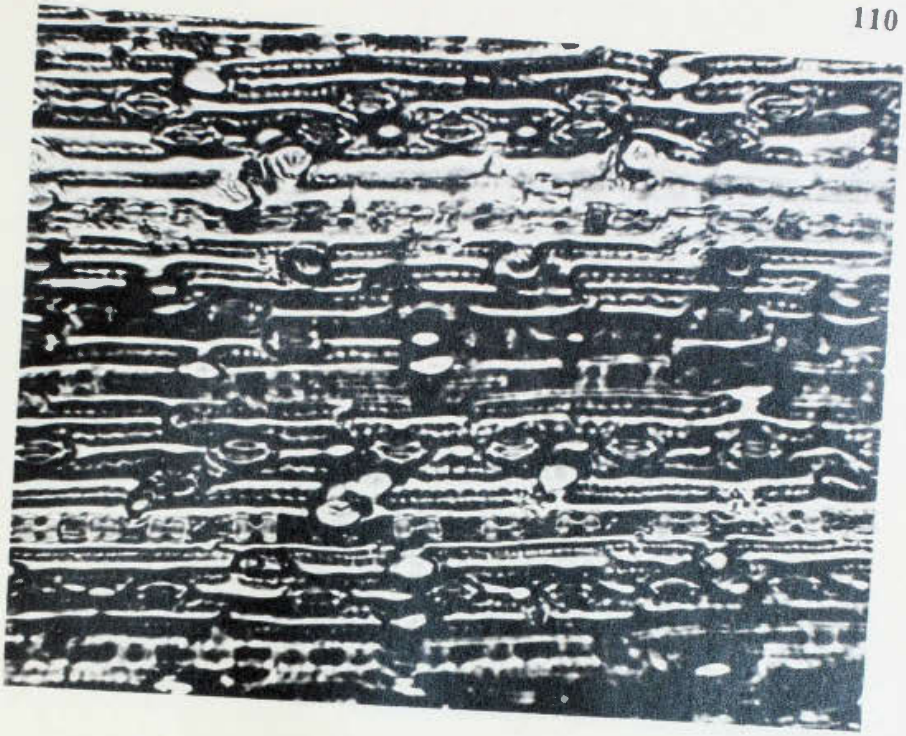


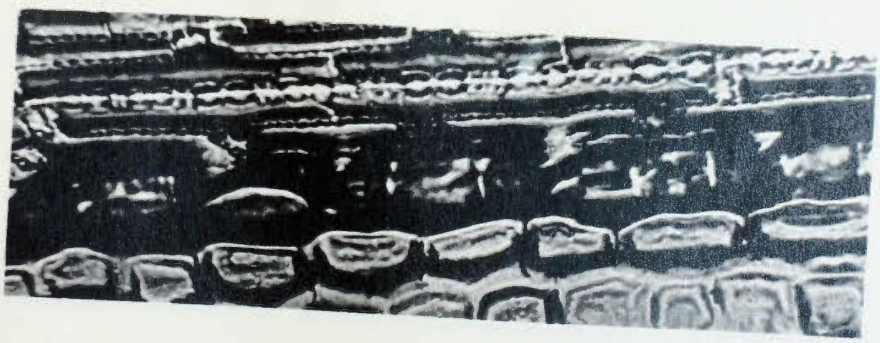
Hyparrhenia cymbaria (L.) Stapf



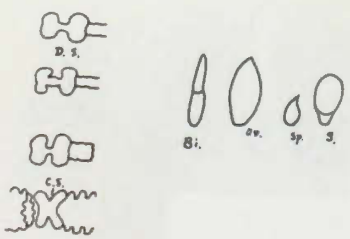
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 50.



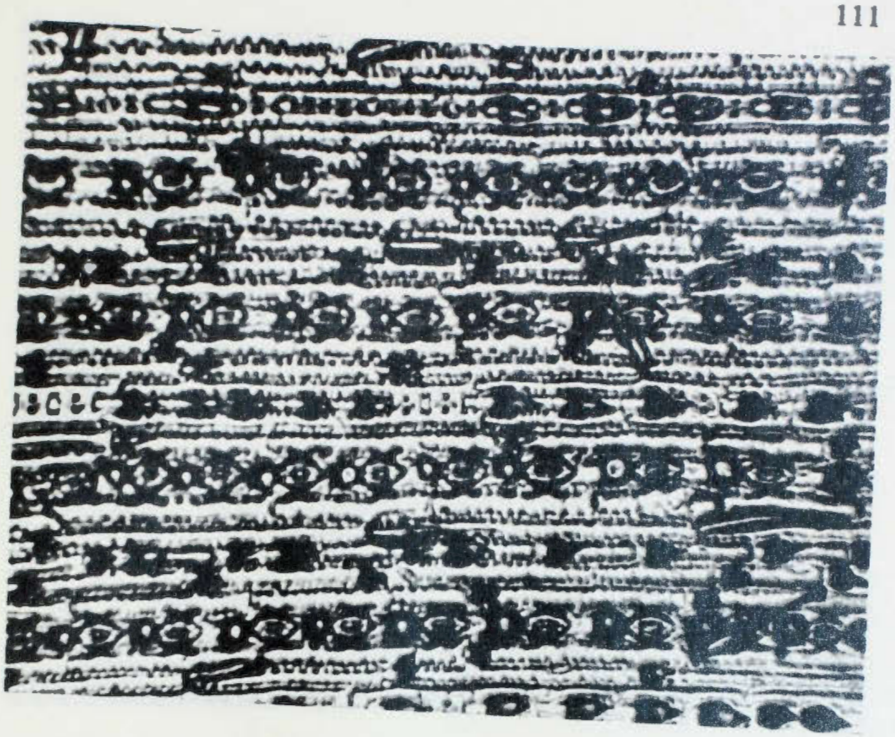


Hyparrhenia diplandra

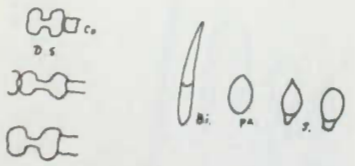


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 60.

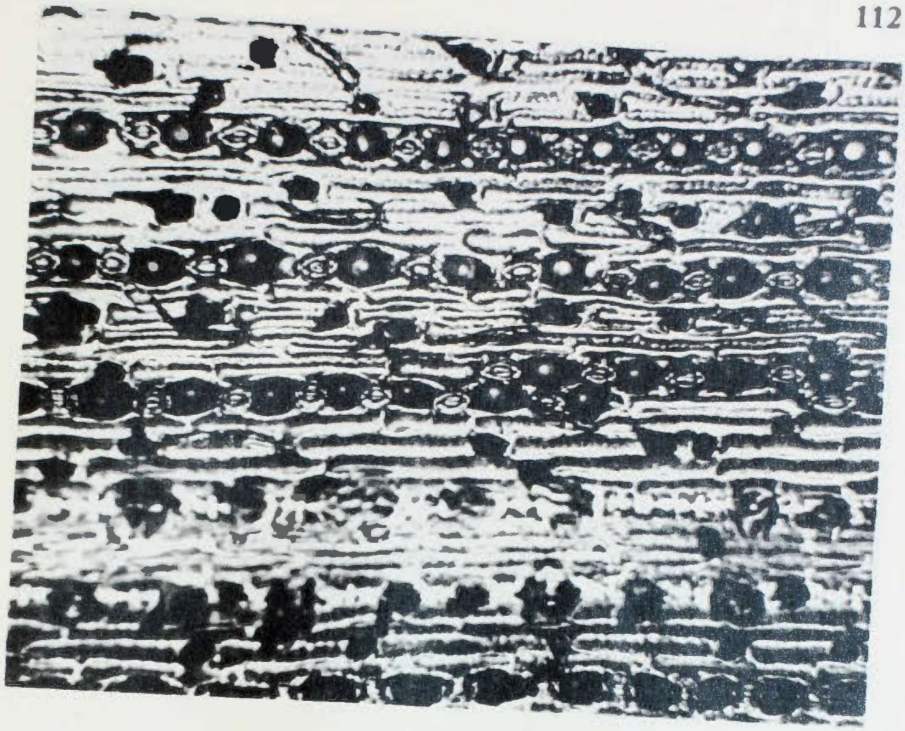


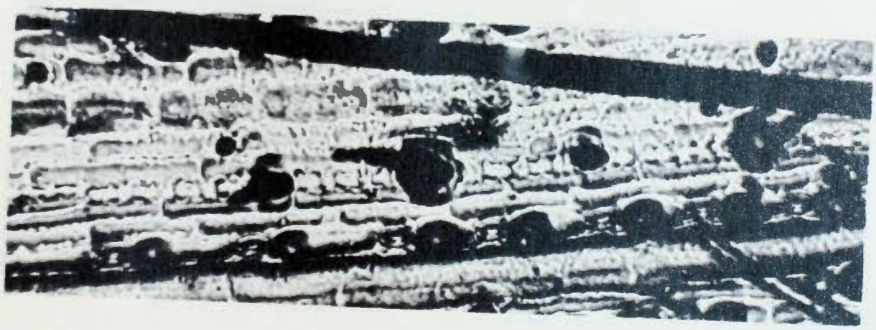
Hyparrhenia edulis
Anglo-Egyp. Sudan

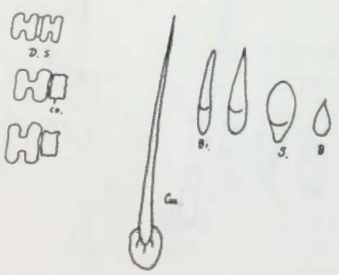


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 61.



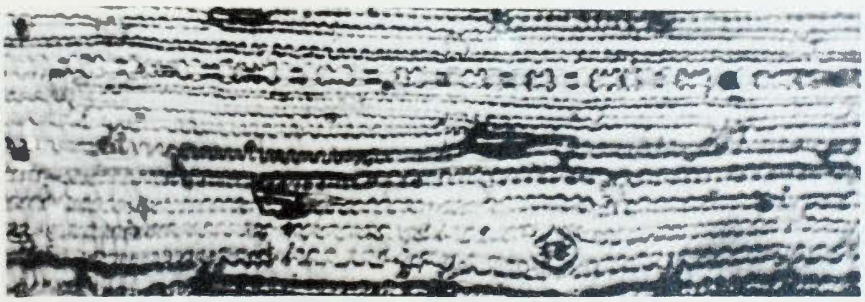




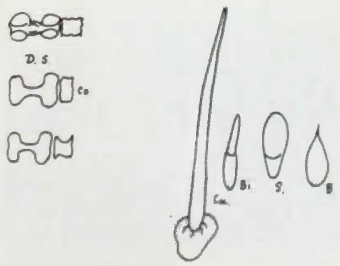
Hyparrhenia edulis
Anglo-Egyp. Sudan

Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 62.

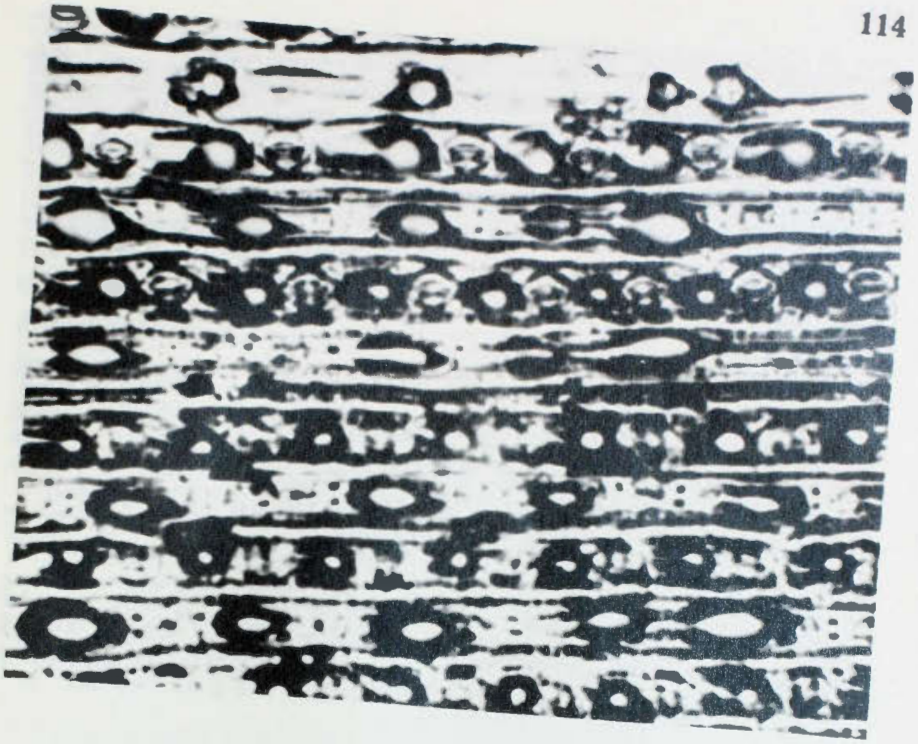


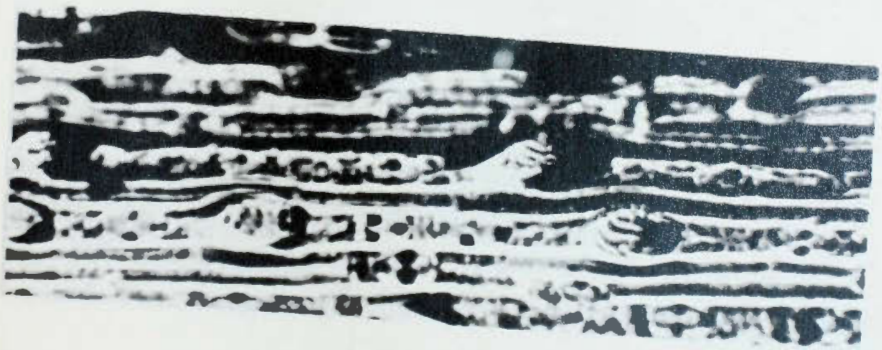
Hyparrhenia familiaris



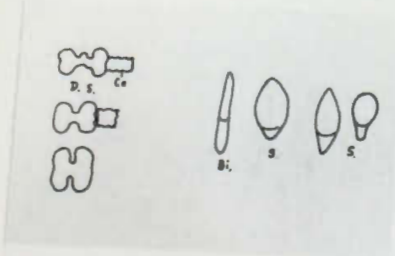
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 63.



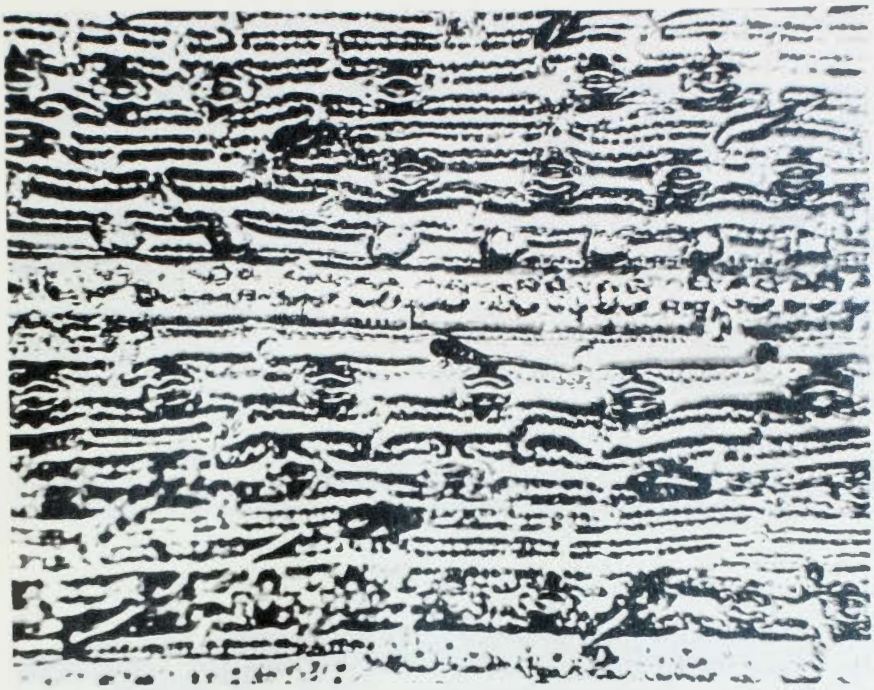


Hyparrhenia hirta (L.) Stapf

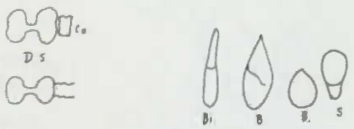


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 64.

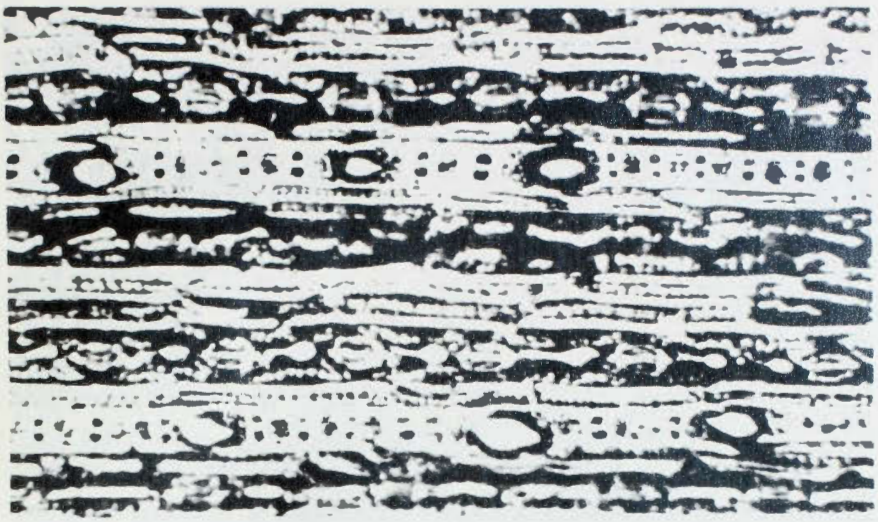


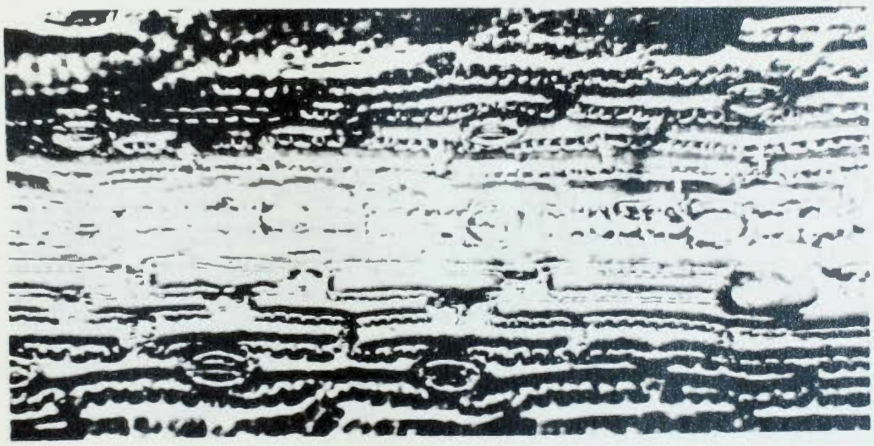
Hyparrhenia rufa
Madagascar



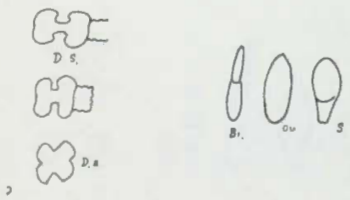
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 65.



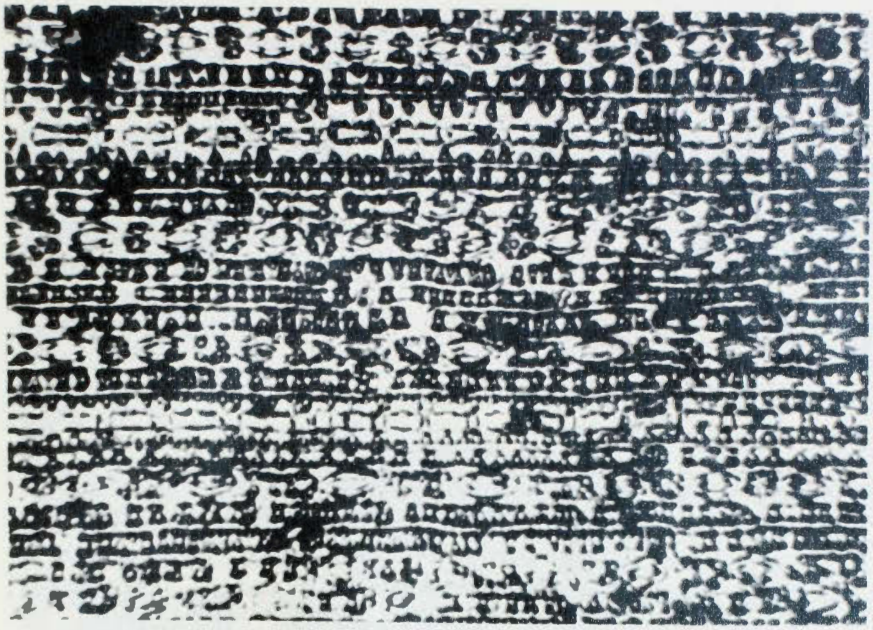


Hyparrhenia rufa (Nees) Stapf
Belgian Congo

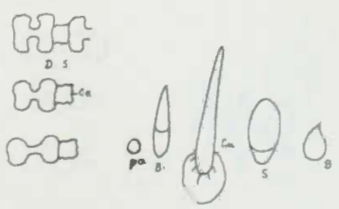


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 66.

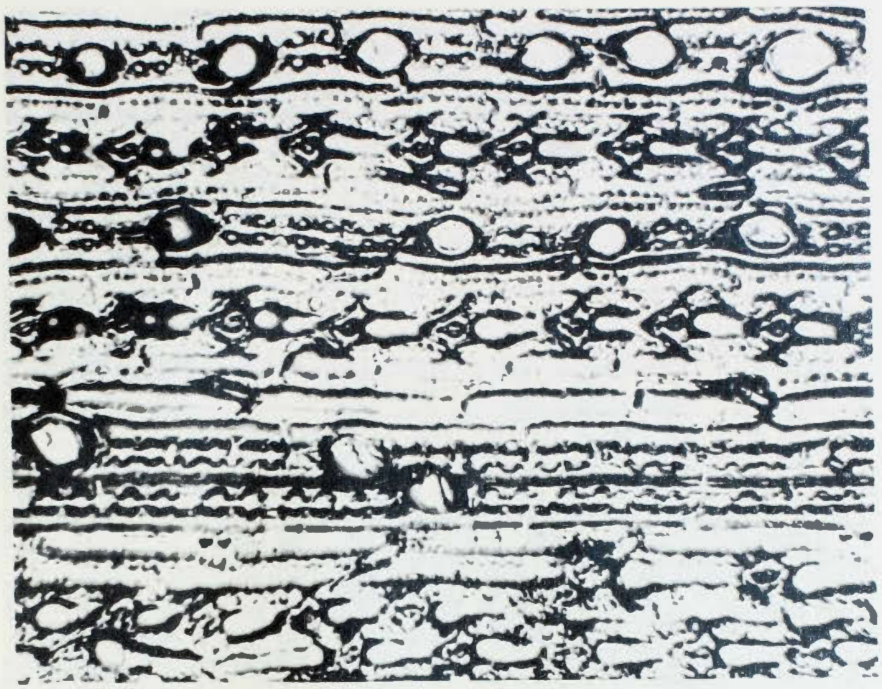


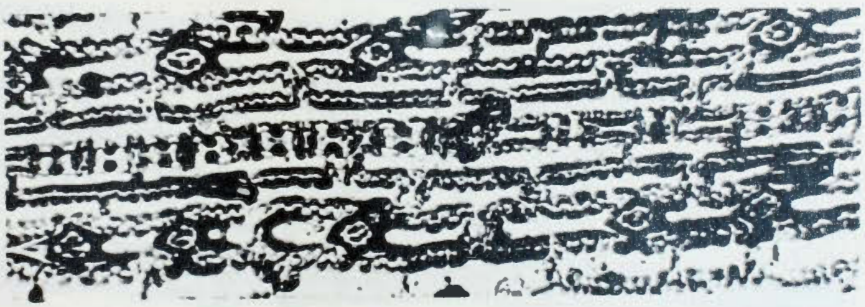
Hyparrhenia ruprechii



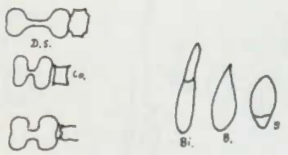
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 67.



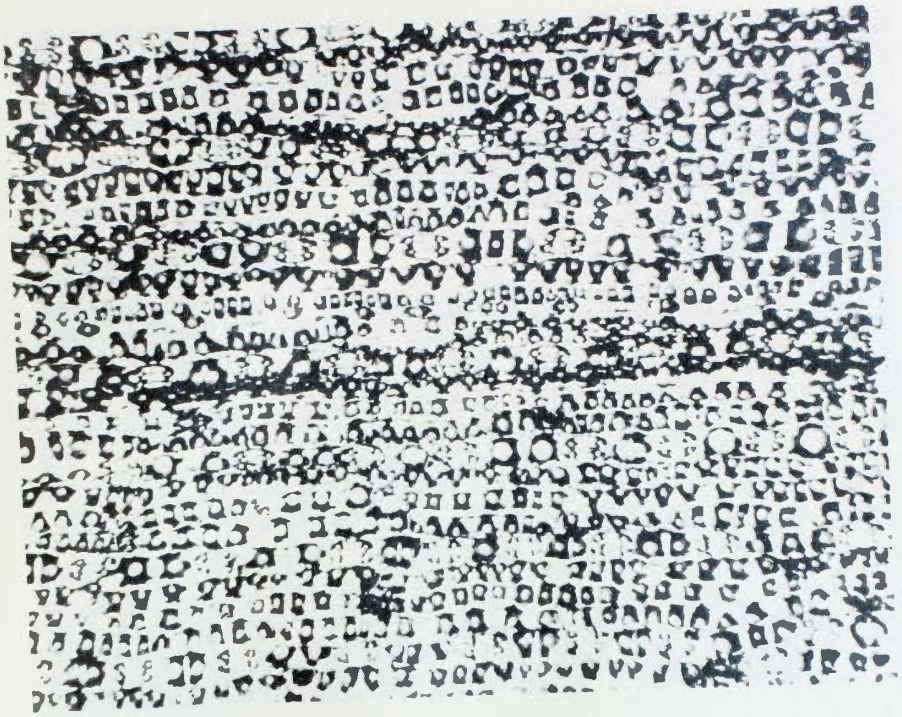


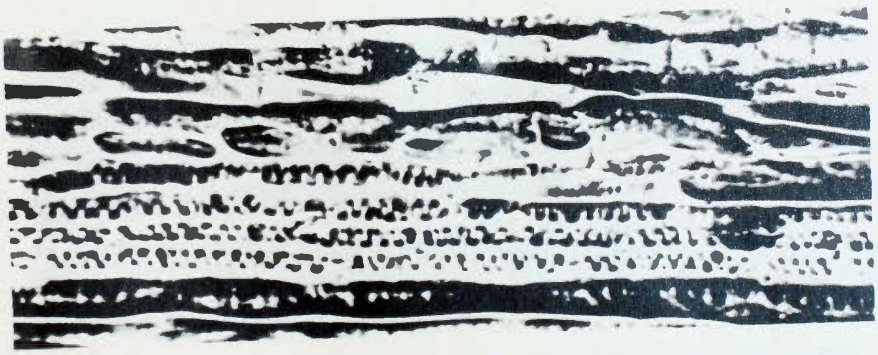
Hyparrhenia welwitschii



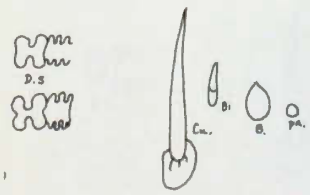
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 48.



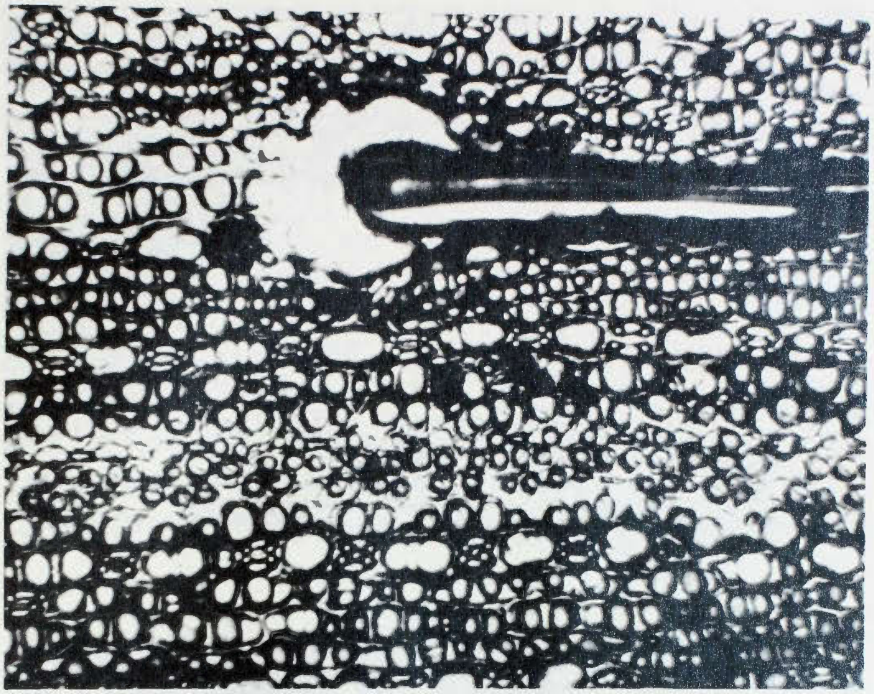


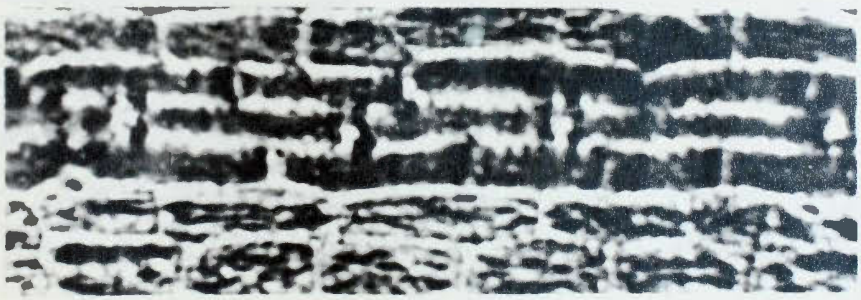
Ischaemum rugosum Salisb.



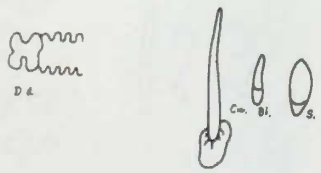
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 69.



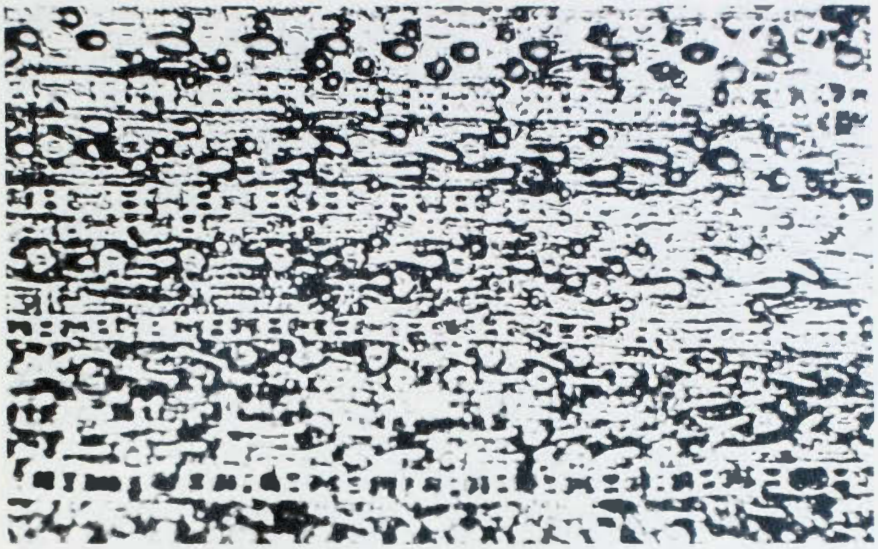


Ischaemum sp. (may be Isolaema)

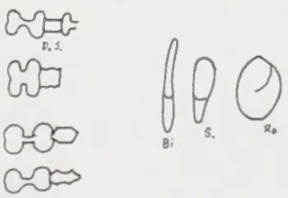


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 70.

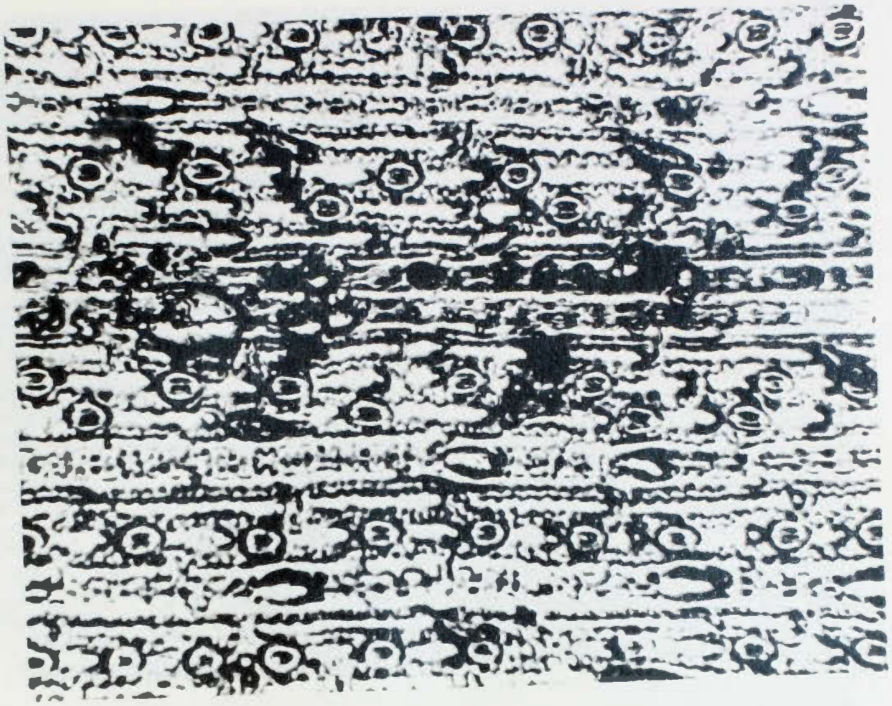


Lseilemo laxum

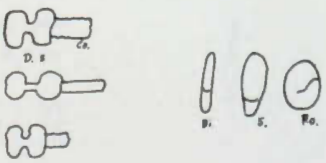


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 71.

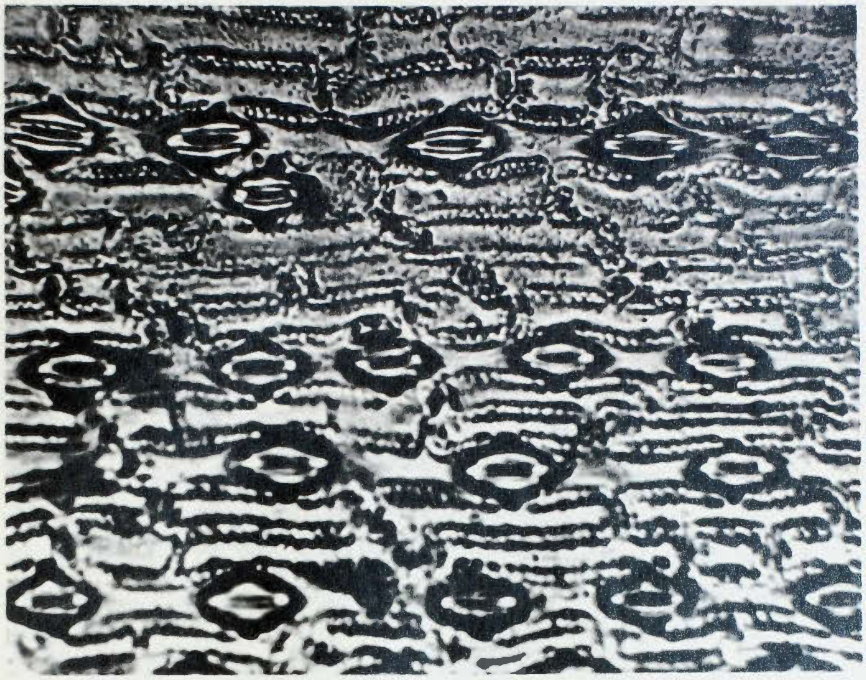


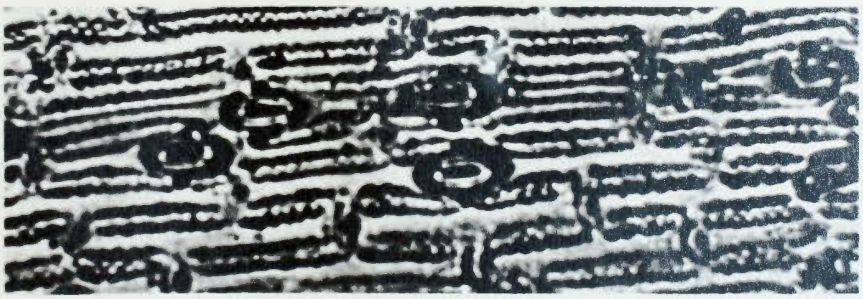
Iseilemo vaginiflorum



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 72.

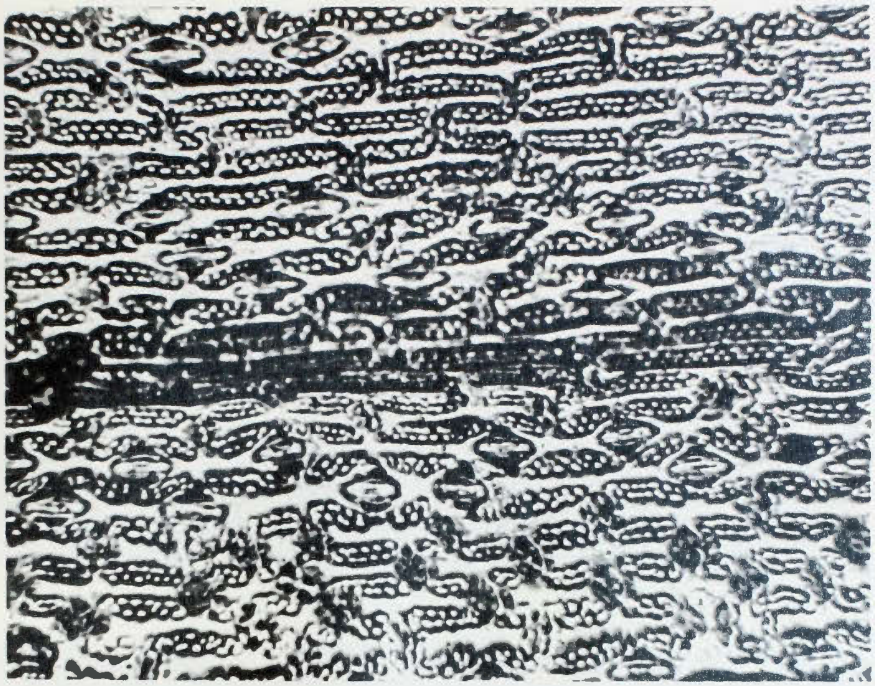


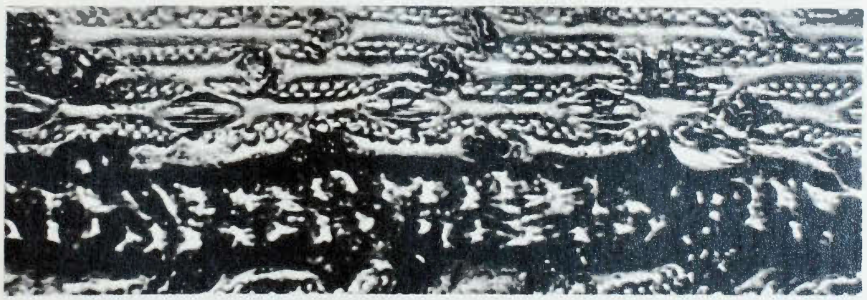


Lasiurus hirsutus (Forsk) Boiss

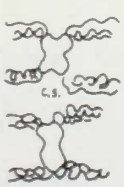
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

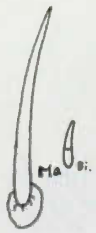
Fig. 73.





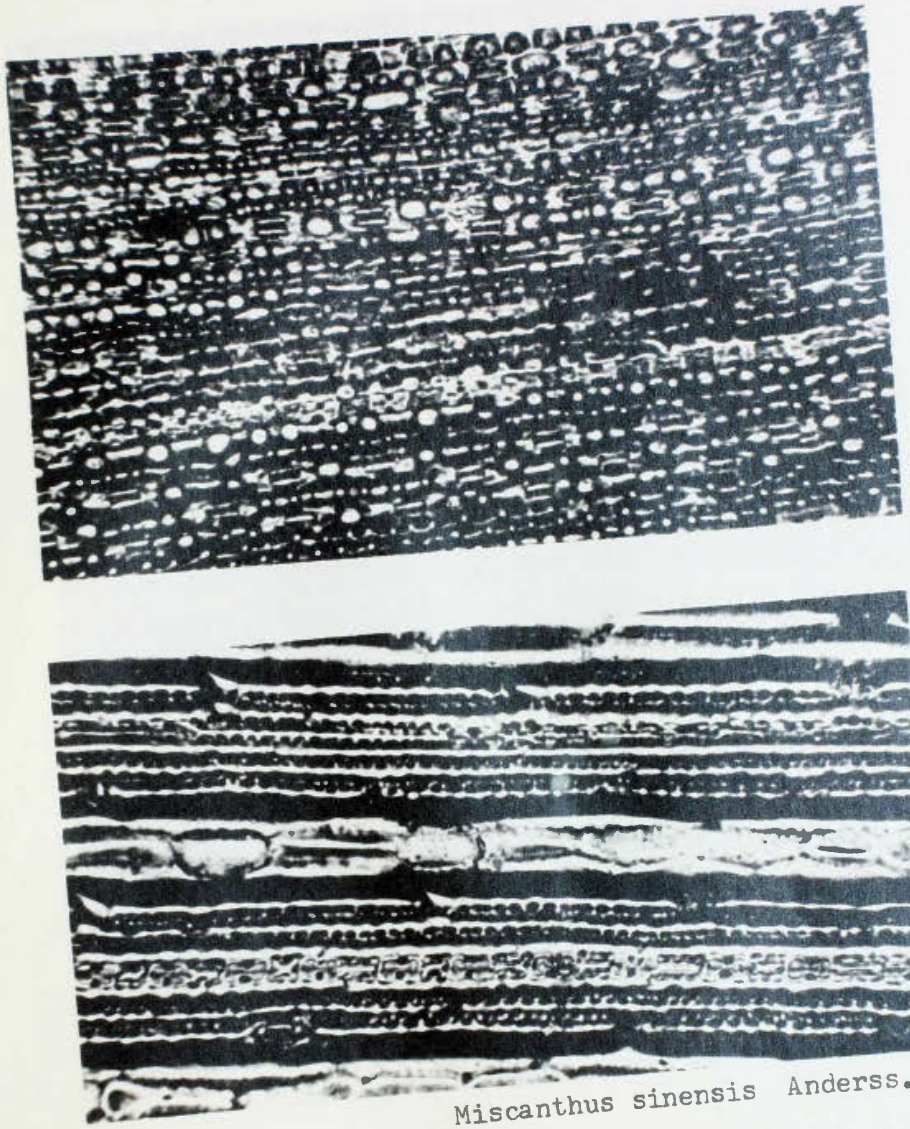
Miscanthidium junceum (Stapf) Stapf
So. Rhodesia (Botany greenhouse)



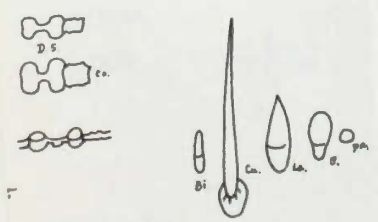


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 7b.

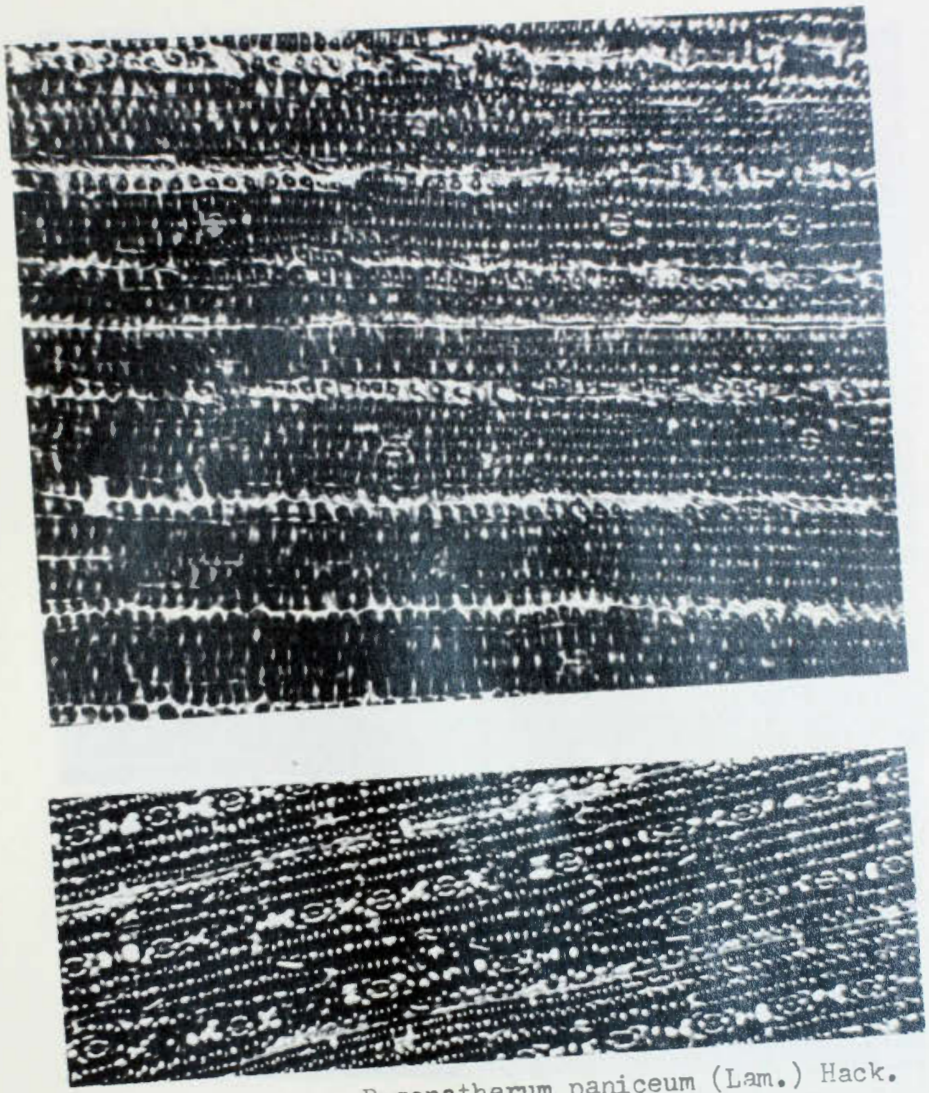


Miscanthus sinensis Anderss.

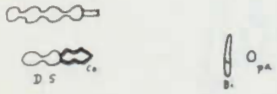


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 75.

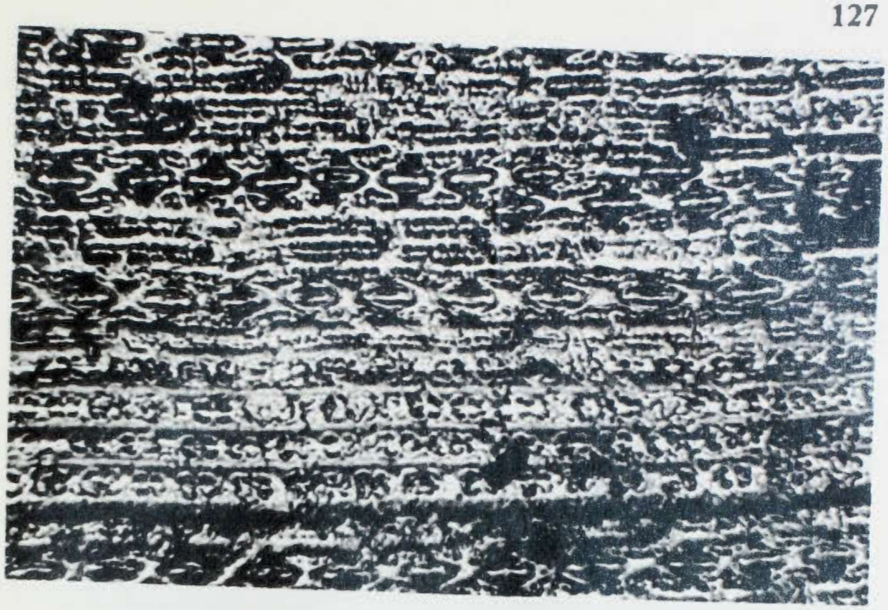


Pogonatherum paniceum (Lam.) Hack.

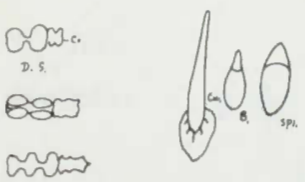


Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 76.

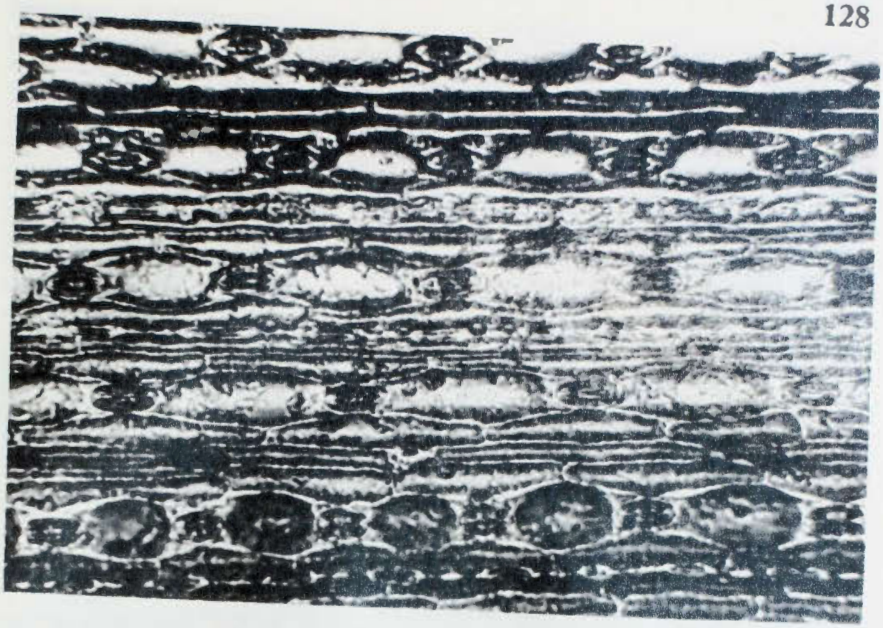


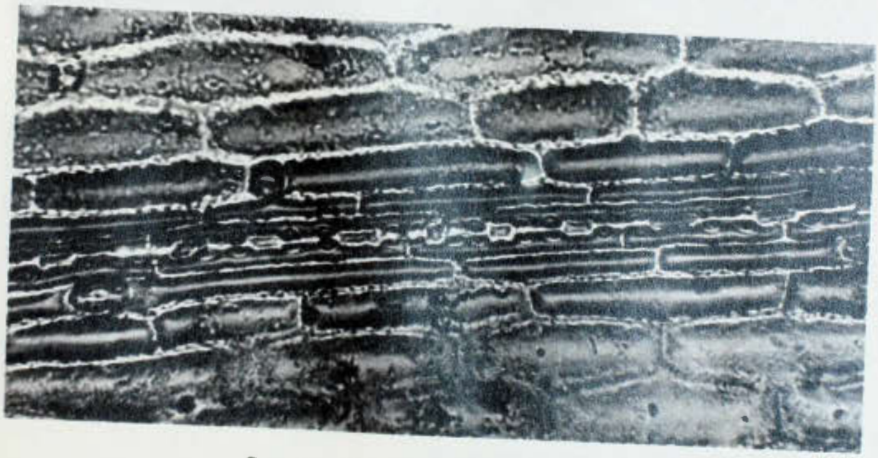
Rottboellia exaltata L.f



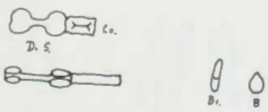
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 77.



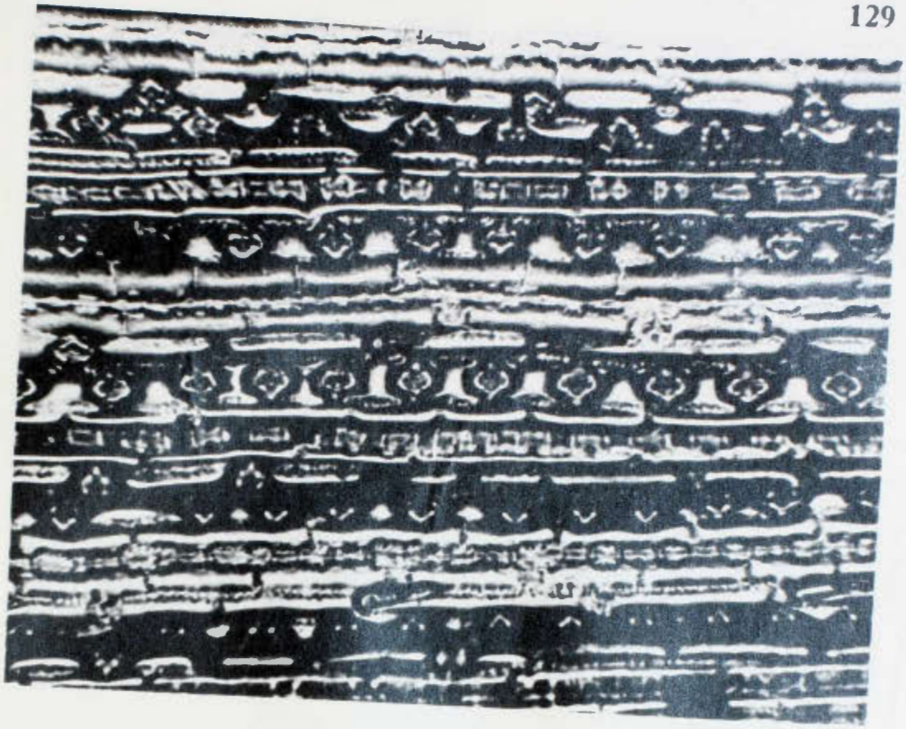


Schizachyrium jeffreysii (Hack.) Stapf



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

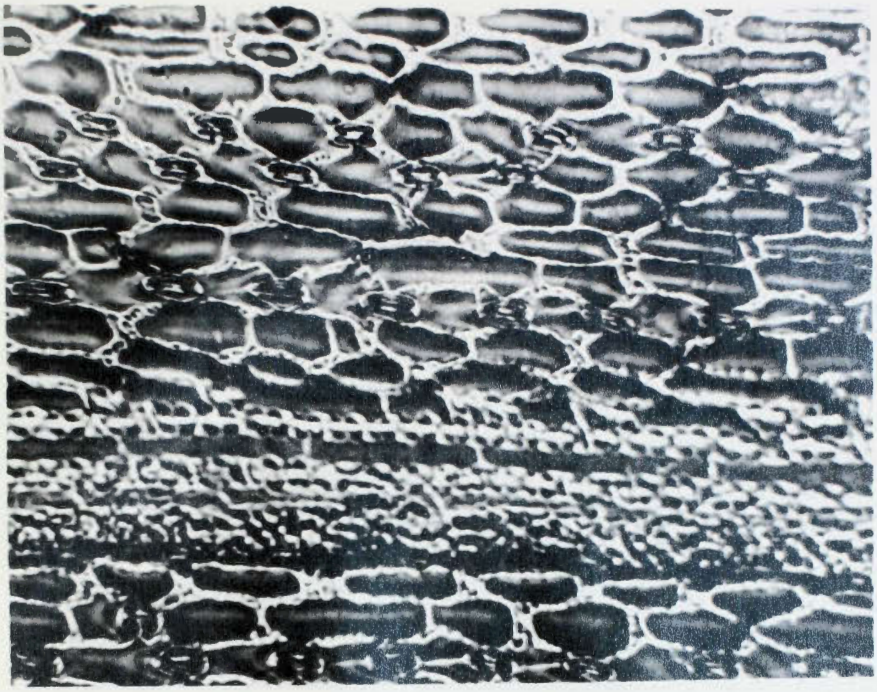
Fig. 78.

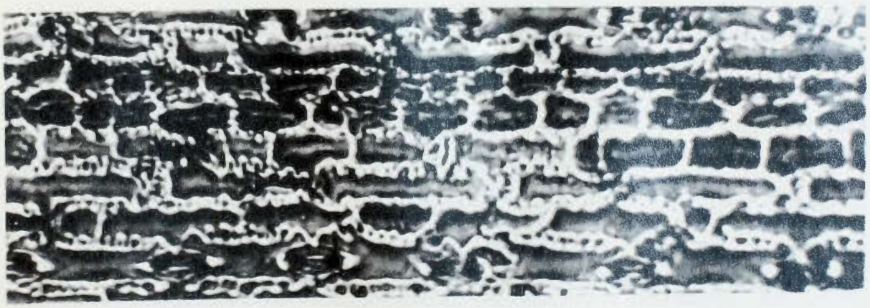


Schizachyrium littoralis

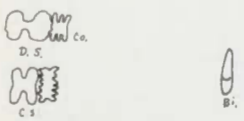
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 79.



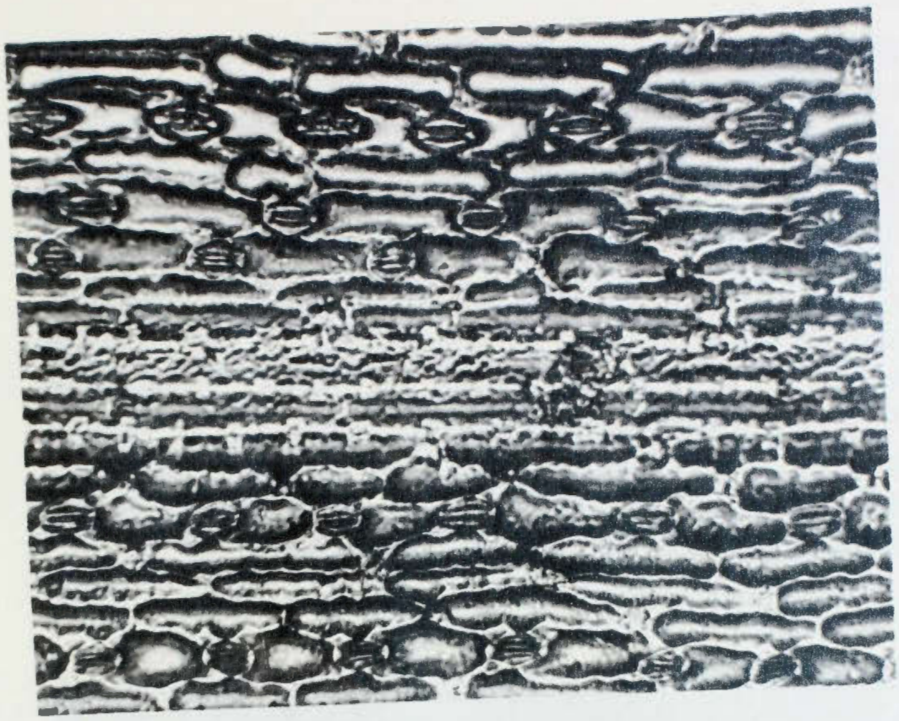


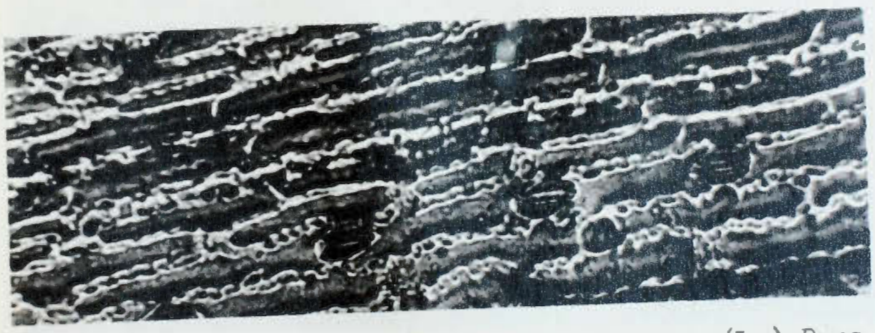
Sorghum aethicpicum



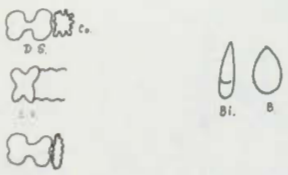
Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 80.



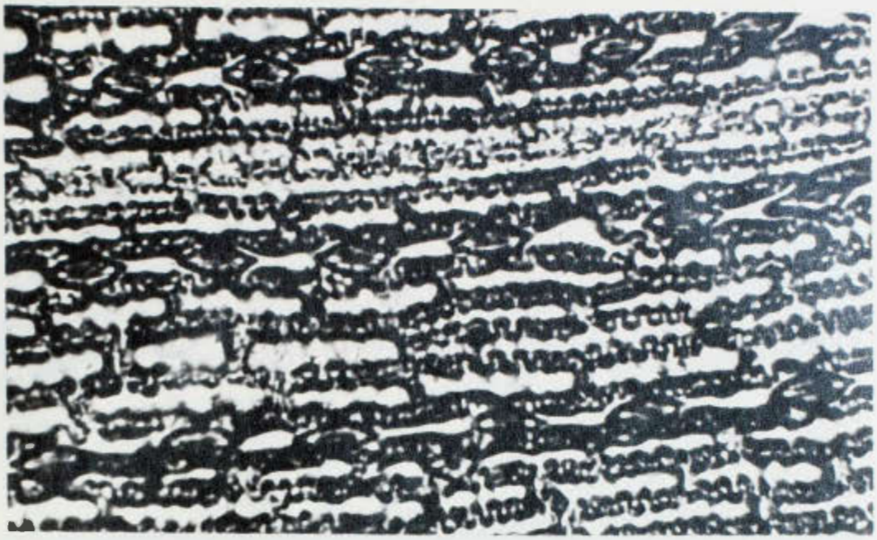


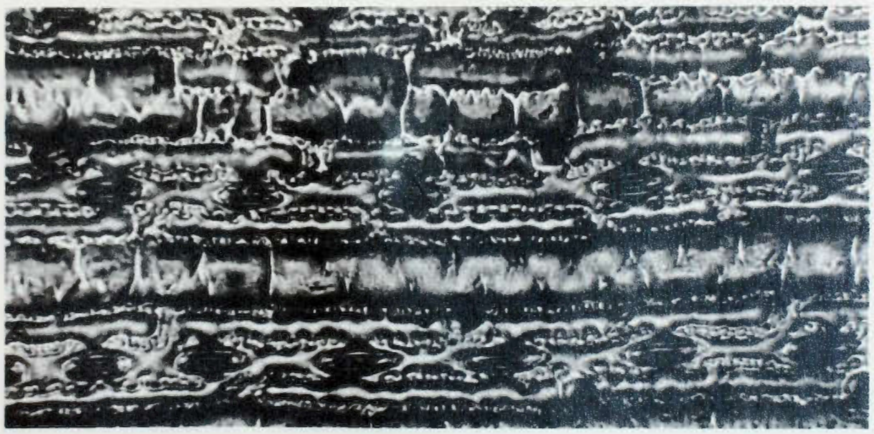
Sorghum halepense (L.) Pers.
Israel



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 81.





Sorghum halepense (L.) Pers.
Dehra Dun, India

Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

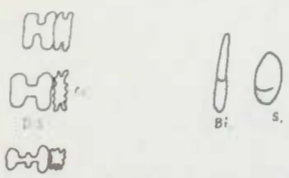
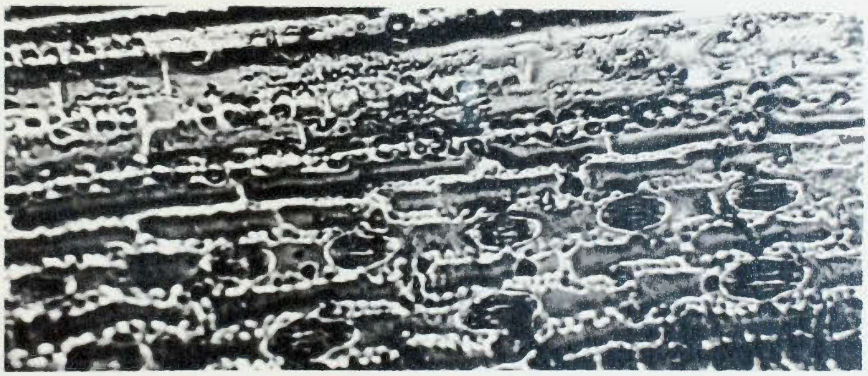
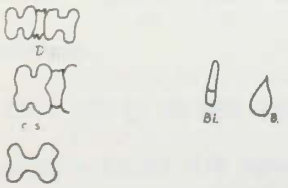


Fig. 82.



Sorghum halepense (L.) Pers.
India



Upper : lower surface
Middle: upper surface
Lower : short cells
and trichomes

Fig. 33.

SUMMARY AND DISCUSSION

This paper includes 23 genera, 71 species or a total of 83 entries of Andropogoneae.

Epidermal patterns were studied mainly by the peel method, using acetone and cellulose acetate film, and compared with peridermal sections and some whole cleared mounts.

General epidermal cell elements, bicellular micro hairs, silica cells, cushion hairs, macrohairs, bulbous hairs, swollen hairs, papillae, spicules and stomata were studied in detail as well as the arrangement. Silica cells may be dumbbell-shaped, nodulose, cruciate, and double-bladed axe-shaped. There are 56 entries of dumbbell-shaped, 18 entries of dumbbell-shaped with nodulose, 7 species of dumbbell-shaped with some cruciate, and 3 species of double bladed-axe or some cruciate.

Bicellular-microhairs were present in 75 entries, or 63 distinct species, and bicellular-microhairs absent on 8 species. Three species have only bicellular hairs and one species has no trichomes.

Stomata and trichomes alternating in the same row occur on 52 entries. Silica cells alternate with trichomes in the same row on 45 entries.

This study showed that bicellular-microhairs and dumbbell-shaped silica cells are common characters of the Andropogoneae.

Also dumbbell-shaped silica cells and variable trichomes are common characters. These elements are Eupanicoid tribe characters according to Prat. No bicellular-microhair species are of the Festucoid type according to Prat (1936). But for these species a more detailed and broader examination is needed.

Almost all entries have trichomes, cushion hairs, swollen hairs, bulbous hairs, papillae and spicules except only one species - Cymbopogon bombycinus.

Bicellular-micro hairs and dumbbell-shaped silica cells are important characters for the Andropogoneae tribe, as well as the genus and species classification. The other elements of trichomes, cushion hairs, swollen hairs, papillae and spicules are more variable in the same species. Many of these elements alternate with silica cells and stomata regularly in certain species. This arrangement of elements silica cells, stomata, and trichomes are more important for identification of species. A single character may be qualitative and of diagnostic valve, whereas, other single characters may vary quantitatively, and are primarily of value only with a group of characters. Both of these, qualitative and quantitative characters are useful for taxonomy of grasses.

A dichotomous key was constructed for the purpose of pointing out the principal diagnostic features of the epidermal patterns as well as surface morphology.

The present paper enables us to add more to the knowledge of

epidermal patterns of selected members of the Bluestem tribe grown in the similar environment of the common transplant garden.

LITERATURE CITED

Arber, Agnes. 1934. The Gramineae. Cambridge University Press. 480.

Esau, K. 1960. Anatomy of Seed Plants. John Wiley and Sons, Inc. 376.

Esau, K. 1957. Plant Anatomy. John Wiley & Sons, Inc. 735.

Lonert, A. C. 1960. Micro-Replica Kit. Turtox News. 38(8):202-203.

Metcalfe, C. R. 1954. Recent work on the systematic anatomy of the monocotyledons. Kew Bull. 1954:523-532.

Metcalfe, C. R. 1960. Anatomy of Monocotyledons, Part II Gramineae. Oxford, Claredon Press. 731.

Prat, H. 1936. "La Systematique des Graminees," Ann. Sci. Nat., Bot., Ser. X 18:165-258.

Prat, H. 1948. General Features of the Epidermis in Zea Mays. Ann. Mo. Bot. Gard. 35:341-351.

Reynolds, H.C. 1959. Morphology of the Leaf Blade in Selected Members of the Andropogoneae with Special Emphasis on Vascularization. University of Nebraska. Ph.D. Thesis (Manuscript).

Tateoka, Tuguo. Sukemitsu Inoue, and Shigeka Kawano. 1959. Notes on some grasses. LX. Systematic Significance of Bicellular Microhairs of Leaf Epidermis. Botanical Gazette, 121(2):80-91.